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SHIELDING OF MANNED SPACE VEHICLES AGAINST PROTONS AND ALPHA PARTICLES

R. G. Alsmiller, Jr., R. T. Santoro,
J. Barish, and H. C. Claiborne

RADIATION SHIELDING INFORMATION CENTER



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R. G. Alsmiller, Jr.
R. T. Santoro
J. Barish*
H. C. Claiborne

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NOVEMBER 1972

NOTE:

Research funded by
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
under Orders H-38280A and H-79272A

*Mathematics Division.

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ABSTRACT

In this report the available information on the shielding of manned space vehicles against protons and alpha particles is summarized. The emphasis in the report is on shielding against Van Allen belt protons and against solar-flare protons and alpha particles, but information on shielding against galactic cosmic rays is also presented.

The report is primarily intended as a handbook for nonexperts in space shielding. For the most part, the approximation methods discussed are those that are standard in the space-shielding literature. However, a large amount of numerical data, not previously published, on the validity of the various approximation methods is presented, and these data may be of interest to those who are familiar with space shielding.

ACKNOWLEDGMENTS

The authors thank F. S. Alsmiller for her numerous comments and suggestions, and for the considerable effort she expended in assisting us in the implementation of many of her suggestions. Thanks are also due to M. O. Burrell of the George C. Marshall Space Flight Center for his continued interest and for many helpful discussions throughout the course of the preparation of this report and to A. Reetz and J. W. Keller of NASA Headquarters who were involved in the initial conception and planning of this work.

Chapter 1

INTRODUCTION

In the past several years the National Aeronautics and Space Administration has sponsored considerable research on the transport methods and physical data needed to design the shielding required to protect astronauts against radiation in space. In this report an attempt is made to summarize the available information on the shielding of manned space vehicles against protons and alpha particles.*

The discussion and results presented are primarily intended for non-experts, and no extensive background in space-radiation or charged-particle-transport theory is presupposed. The emphasis throughout the report is on the magnitude of the physical effects that enter into shield-design calculations and on approximate calculational methods that, for most space-shielding purposes, adequately account for these physical effects. The geometric model used throughout the report is that of a spherical shell shield with a tissue sphere at its center. This configuration resembles only very approximately a real spacecraft with men inside, but it does serve to illustrate many of the significant features of spacecraft shield design. The report is primarily concerned with the shielding of man, but much of it will be of interest to those concerned with the shielding of equipment.

^{*}A summary of the available information on the shielding of manned space vehicles against electrons is being prepared by D. C. Shreve and J. A. Lonergan of Science Applications, Inc.

TShielding against heavier nuclei is not considered in the body of the report, but some approximate information on shielding against the heavy nuclei in galactic cosmic rays is given in Appendix 4.

A large amount of numerical data is presented to aid mission planners who must decide with little effort whether a radiation hazard is likely to exist on a particular mission. If a radiation hazard is thought to exist, then the discussion of the shielding methods and computer codes given in the report should serve as a starting point for obtaining more adequate information.

Essentially all of the numerical results given in this report were obtained with computer codes that are available from the Radiation Shielding Information Center of the Oak Ridge National Laboratory. A bibliography of space-shielding literature containing many references not cited in this report is also available from the Radiation Shielding Information Center.

In Chapter 2 a description of the radiation sources in space is given and examples of the proton and alpha-particle spectra that might be incident on a spacecraft are presented. The transport equations that are applicable in space shielding and the methods of dose calculation are discussed in Chapter 3. Also in Chapter 3, several approximation methods useful in space-shielding calculations are introduced. In Chapter 4 the physical data needed to carry out shielding calculations for incident protons and alpha particles are discussed, and the data used in obtaining the numerical results presented in the report are given. In Chapter 5 radiation protection guidelines are very briefly discussed. Chapter 6 contains a variety of numerical results related to the shielding of spacecraft against Van Allen belt protons and against solar-flare protons and alpha particles. It is in Chapter 6 that the validity of various approximate shielding methods,

^{1.} M. P. Guthrie and R. G. Alsmiller, Jr., "Bibliography, Subject Index, and Author Index of the Literature Examined by the Radiation Shielding Information Center - Space and Accelerator Shielding," Oak Ridge National Laboratory Report ORNL-RSIC-11 (Rev. 2), 1970.

e.g., neglecting particles produced by nuclear reactions, is considered. Computed results obtained with two complex geometry codes, i.e., codes that may be used to carry out shielding calculations for spacecraft of arbitrary geometric complexity, are also presented in Chapter 6. In Chapter 7 the shielding of spacecraft against galactic cosmic-ray protons is considered. In Appendix 1 the solution to the primary-proton transport equation is derived. This solution is used throughout the report and is the basis for much of the work described. In Appendix 2 tables of absorbed dose and dose equivalent are presented for a variety of incident-particle spectra, shield thicknesses, and shield materials. In Appendix 3 the details of obtaining the calculated results presented in Chapters 6 and 7, which include the production and transport of particles from nuclear reactions, are presented. Appendix 3 also contains data, not given in Chapters 6 and 7, on the contribution of the particles produced by nuclear reactions to space-shielding calculations. In Appendix 4 very approximate information on shielding against galactic cosmic-ray alpha particles and heavier nuclei is given.

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Chapter 2

RADIATION SOURCES IN SPACE

In general, there are three natural sources of radiation that influence spacecraft shield design: radiation trapped in the earth's magnetic field (Van Allen belts), solar cosmic rays, and galactic cosmic rays. Depending on the mission, each of these radiation sources can contribute appreciably to the radiation hazard associated with space travel. The characteristics of each of these sources, which are of importance in space-vehicle shielding, are discussed briefly in the sections to follow. More detailed discussions will be found in the books by Haffner, Hess, 3,4 LeGalley and Rosen, 5 McCormac, 6 and Glasstone, 7 and in the Encyclopedia of Physics. 8

^{2.} J. W. Haffner, Radiation and Shielding in Space, Academic Press, New York and London, 1967.

^{3.} W. N. Hess, <u>The Radiation Belt and Magnetosphere</u>, Blaisdell Publishing Co., Waltham, Mass., Toronto, London, 1968.

^{4.} W. N. Hess, Ed., <u>Introduction to Space Science</u>, Gordon and Breach Science Publishers, New York, London, Paris, 1965.

^{5.} D. P. LeGalley and A. Rosen, Eds., <u>Space Physics</u>, John Wiley & Sons, Inc., New York, London, Sydney, 1964.

^{6.} B. M. McCormac, Ed., Radiation Trapped in the Earth's Magnetic Field, D. Reidel Publishing Co., Dordrecht, Holland, and Gordon and Breach Science Publishers, New York, 1966.

^{7.} S. Glasstone, Sourcebook on the Space Sciences, D. Van Nostrand Co., Inc., Princeton, N. J., Toronto, Ont., New York, London, 1965.

^{8.} S. Flugge, Ed., Encyclopedia of Physics; Vol. 46/1 and 46/2, Cosmic Rays, Springer-Verlag, 1961.

2.1 VAN ALLEN BELTS

The radiation hazard to space vehicles in orbit about the earth is due primarily to the charged particles trapped in the earth's magnetic field. In the following sections, the available information about particle fluxes in the Van Allen belts, particularly the Van Allen proton belt, pertinent to shielding is described. The most generally usable models of the radiation environment in the Van Allen belts are those due to Vette and his coworkers, 9-14 and it is therefore the work of these investigators that is emphasized here.

2.1.1 Characteristics of the Van Allen Belts

There is only one radiation belt surrounding the earth, but when the energy distributions of the protons and electrons trapped in the earth's magnetic field are considered, two reasonably distinct zones - the inner and outer Van Allen belts - may be distinguished. The charge density is approximately the same in both zones, but the energy distribution of the protons in the inner zone extends to energies of the exder of hundreds of MeV, and the energy distribution of the electrons in the outer zone extends

^{9.} J. I. Vette, "Models of the Trapped Radiation Environment. Vol. I: Inner Zone Electrons and Protons," NASA SP-3024, 1967.

^{10.} J. I. Vette, A. B. Lucero, and J. A. Wright, "Models of the Trapped Radiation Environment. Vol. II: Inner and Outer Zone Electrons," NASA SP-3024, 1966.

II. J. I. Vette and A. B. Lucero, "Models of the Trapped Radiation Environment. Vol. III: Electrons at Synchronous Altitudes," NASA SP-3024, 1967.

^{12.} J. N. King, "Models of the Trapped Radiation Environment. Vol. IV: Low Energy Protons," NASA SP-3024, 1967.

^{13.} J. P. Lavine and J. I. Vette, "Models of the Trapped Radiation Environment. Vol. V: Inner Belt Protons," NASA SP-3024, 1969.

^{14.} J. P. Lavine and J. I. Vette, "Models of the Trapped Radiation Environment. Vol. VI: High Energy Protons," NASA SP-3024, 1970.

to energies of the order of several MeV. Since this report is concerned with shielding against high-energy protons, the inner zone is of primary interest here.

The proton flux per unit energy at a given location in the Van Allen proton belt, the inner zone, is approximately constant in time. Some variations with time do occur, but for most shielding purposes these variations are not significant.

The proton flux per unit energy in the Van Allen proton belt is a strongly varying function of altitude above the earth's surface and of position around the earth. Very approximately, the proton belt extends from an altitude above the earth's surface of a few hundred nautical miles to several thousand nautical miles. An important exception to the lower altitudes occurs in the vicinity of 35° south latitude and 325° east longitude where the proton flux is appreciable at altitudes as low as 150 nautical miles. This "dip" is referred to as the South Atlantic anomaly and is very important in mission planning since most of the radiation hazard to occupants of space vehicles in low orbits comes from passing through the region of the anomaly. A space vehicle in an orbit that follows the equator (0° inclination) would miss the anomaly completely, and the radiation hazard is insignificant for this inclination at altitudes of less than approximately 250 nautical miles. The maximum hazard for low orbits occurs at an approximately 30° inclination to the equatorial plane since spacecraft in such orbits pass through the anomaly more often. Proton isoflux contours at an altitude of 240 nautical miles and in the vicinity of the anomaly are shown in Fig. 2.1. 15 The proton flux as a function of time is shown in Fig. 2.2

^{15.} N. O. Burrell, J. J. Wright, and J. W. Watts, "An Analysis of Energetic Space Radiation and Dose Rates," NASA TN D-4404, 1968.

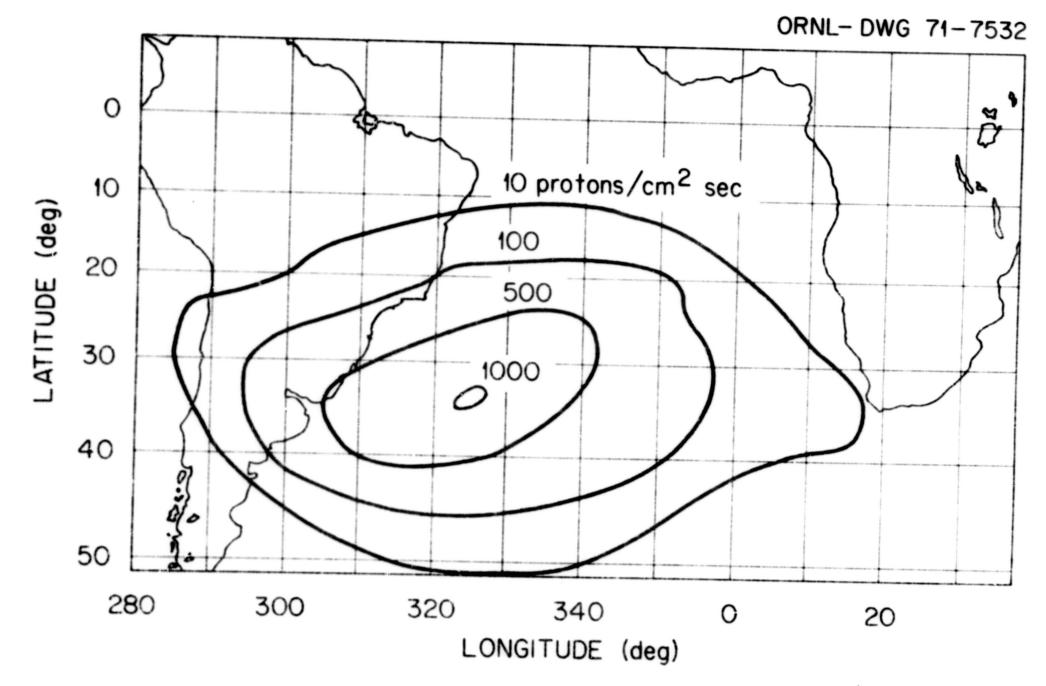


Fig. 2.1. Proton isoflux contours for an altitude of 240 nautical miles.

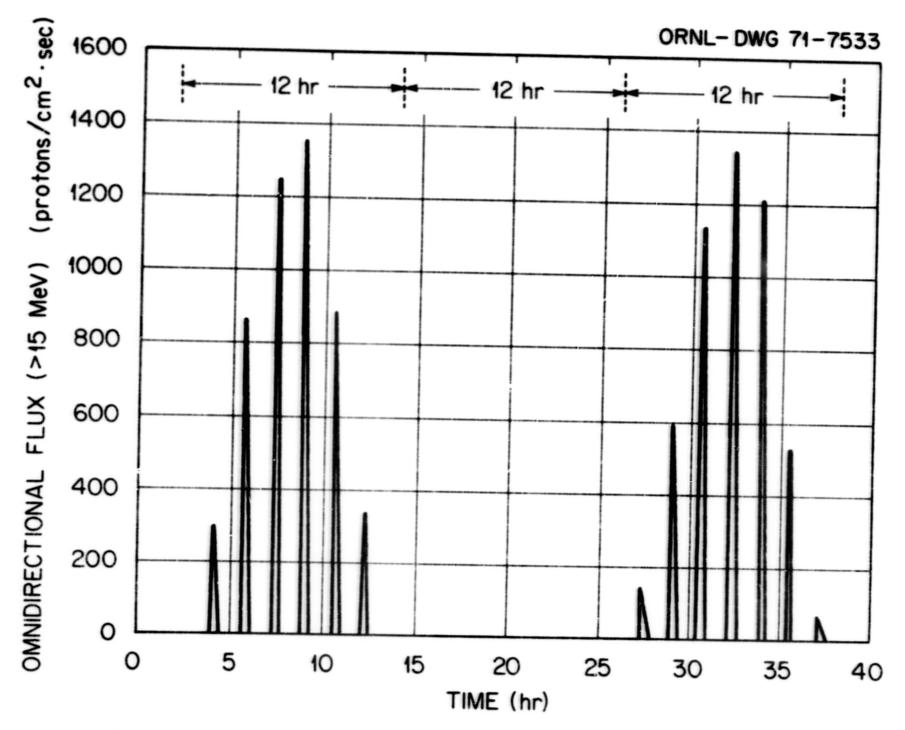


Fig. 2.2. Proton flux as a function of time for a circular orbit at an altitude of 240 nautical miles and an inclination of 30° .

for a space vehicle in a circular orbit at an altitude of 240 nautical miles and at a 30° inclination to the equatorial plane. Each "spike" in Fig. 2.2 corresponds to a passage through the anomaly.

It should be clear from this discussion that the radiation hazard to the occupants of an orbiting vehicle is very dependent on the orbit. The manner in which the proton flux per unit energy that is incident on a space-craft traveling in a specific orbit may be obtained is described in the next several sections of this report.

2.1.2 The B,L Coordinate System

Considerable difficulties were encountered in early attempts to understand the measured intensities of particles at various positions in the Van Allen belts. McIlwain¹⁶ was able to show that measurements made at different geographic locations could be systematized by introducing a set of coordinates that take into account the nondipole nature of the earth's magnetic field and the properties of the motion of charged particles in slowly varying magnetic fields.¹⁷ The coordinates used by McIlwain are the magnetic field intensity, B, and the magnetic shell parameter, L. In the earth's magnetic field, the magnetic shell parameter defined in Ref. 16 is only approximately constant along magnetic lines of force and has no simple geometric interpretation. If, however, the earth's magnetic field were a dipole field, then the magnetic shell parameter would be constant along magnetic lines of force and would be equal in magnitude to the radial distance

^{16.} C. E. McIlwain, "Coordinates for Mapping the Distribution of Magnetically Trapped Particles," J. Geophys. Res. 66, 3681 (1961).

^{17.} T. G. Northrop and E. Teller, "Stability of the Adiabatic Motion of Charged Particles in the Earth's Field," Phys. Rev. <u>117</u>, 215 (1960).

in the equatorial plane from the center of the earth to a magnetic field line. The geometry of the B,L coordinates is shown schematically in Fig. 2.3.

The use of the B,L coordinates in representing particle intensities in the Van Allen belts has become standard, and this is the coordinate system that has been used by Vette $et\ al.^{9-14}$ in preparing the models of the Van Allen proton belt considered in the next section.

2.1.3 Models of the Van Allen Proton Belt

The task of correlating and systematizing the large amount of experimental data on particle fluxes in the Van Allen belts has been carried out by Vette and his coworkers. 9-14 The general procedure in the case of the proton belt was to convert all data to omnidirectional integral flux as a function of B and L (see Section 2.1.2) and then to fit this flux at a particular value of B and L with an equation of the form

$$J(>E,B,L) = J(>E_1,B,L) \exp \left[-\frac{E-E_1}{E_0(B,L)}\right]$$
 (2.1)

or

$$J(>E,B,L) = J(>E_1,B,L) \left[\frac{E}{E_1}\right]^{P(B,L)}$$
, (2.2)

where

J(> E,B,L) = the omnidirectional flux of protons with energy > E
 at a particular point in B,L space,

 $E_1 = a$ constant energy that is independent of B and L,

 E_o , P = the fit parameters that are functions of B and L.

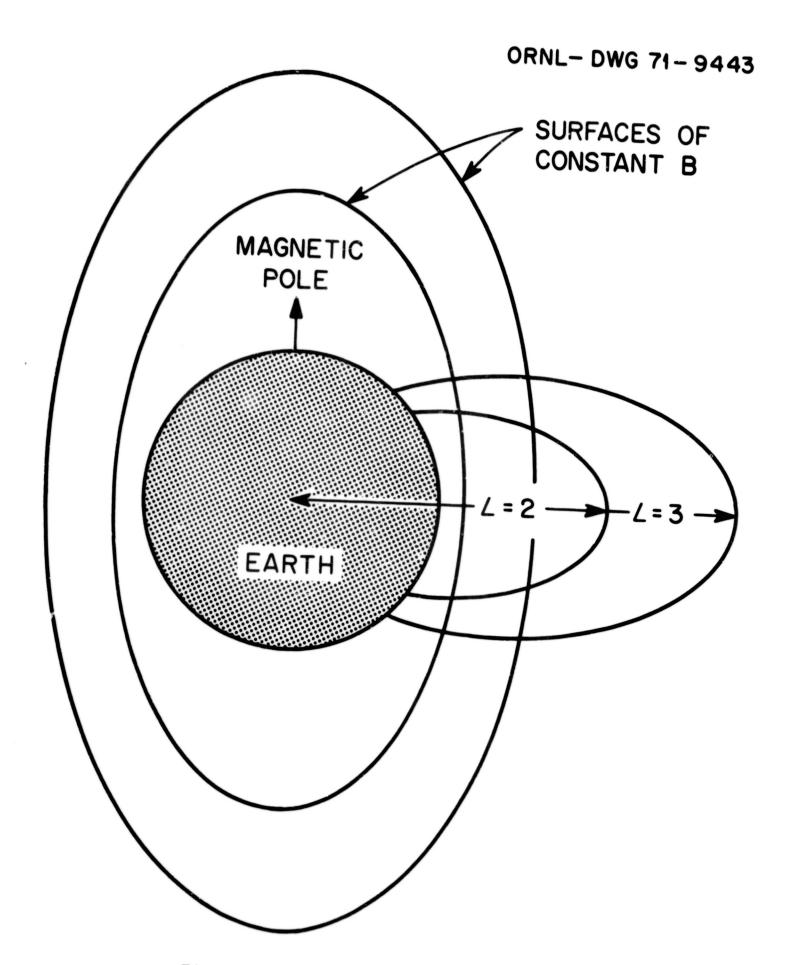


Fig. 2.3. The B,L coordinate system.

In order to fit the experimental data to the desired accuracy in the form given by Eqs. 2.1 or 2.2, it was necessary to use different parameters in different energy ranges. Thus, initially five proton models, AP5, AP4, AP2, AP1, and AP3, covering the energy ranges 0.1 to 4 MeV, 4 to 15 MeV, 15 to 30 MeV, 30 to 50 MeV, and > 50 MeV, respectively, were produced. Later, when additional data became available, two additional models were produced: AP6, 13 which superseded AP2 and AP4 for the energy range 4 to 30 MeV, and AP7, 14 which superseded AP3 for energies > 50 MeV. In general, it has been found that there is little difference in the goodness of fit obtained with exponential and power-law functions, and Eq. 2.1 was used in all of the models except AP6. 13 These models represent the best available information on the proton spectra in the Van Allen belt, but because of the lack of experimental information in various regions of B,L and at energies above approximately 200 MeV, there is considerable uncertainty in some of the data provided by the models. 9-14

The omnidirectional differential energy distribution of the protons at particular B,L values may be obtained by differentiating Eq. 2.1 or, in the case of the AP6 model, Eq. 2.2. It is important to note that in their present form the models do not give any information about the angular distribution of the protons at a particular point in B,L space. The data for all of the models are available on punched cards from the National Space Science Data Center at the Goddard Space Flight Center, Greenbelt, Maryland. The manner in which these data may be used to obtain the proton flux per unit energy that is incident on an orbiting spacecraft is discussed in the next section.

2.1.4 Orbital Integration

To carry out space-shielding calculations, it is necessary to know the energy and angular distributions of the radiation that is incident on the spacecraft. In orbiting through the Van Allen belts, a spacecraft will pass through many different B,L values and will therefore pass through many different parts of the radiation environment. To determine the particle flux that is incident on the spacecraft, it is necessary to determine the B and L coordinates of the spacecraft as a function of time and carry out an integration over time using the flux models described in the previous section. The average omnidirectional flux of particles with energy > E, J(> E), that is incident on the spacecraft may be written

$$J(>E) = \frac{1}{T} \int_{0}^{T} J[>E,B(t),L(t)]dt$$
, (2.3)

where

B(t),L(t) = the coordinates of the spacecraft in B,L space at time t,

T = a time that must be taken sufficiently large that J(> E) is independent of T.

A computer code, TRECO, 18 is available to carry out numerically the integration in Eq. 2.3. For any given set of initial conditions, this code determines the spacecraft position as a function of time by solving the equations of motion of a spacecraft in a gravitational field and then

^{18. &}quot;Data Users' Note: TRECO, an Orbital Integration Computer Program for Trapped Radiation," National Space Science Data Center, Goddard Space Flight Center, NASA Document NSSDC-68-02, 1968.

uses the radiation models of Vette et al. (see previous section) to determine J(> E) by means of Eq. 2.3. The time T required to obtain a good average is dependent on the particular orbit being considered, but times of the order of one to two days are often sufficient. The omnidirectional differential flux is obtained with the code TRECO by assuming that the derivative of Eq. 2.3 with respect to energy may be approximated by a constant over a small energy interval; that is, the omnidirectional differential flux is computed in TRECO by the equation

$$-\frac{dJ(>E)}{dE} = \frac{J(>E_B) - J(>E_A)}{E_B - E_A}, \qquad E_A \le E \le E_B, \qquad (2.4)$$

where the energy-group boundaries must be specified by the user.

The angular distribution of the particles that are incident on the spacecraft is not provided by TRECO. Since it is necessary to know this angular distribution to carry out shielding calculations, the assumption is usually made that this distribution is isotropic. It must be understood that this assumption is made because of the lack of adequate data, and in some cases it may lead to poor results.

2.1.5 Omnidirectional Differential Proton Fluxes Corresponding to Circular Orbits in the Van Allen Belts

In this section omnidirectional differential proton fluxes obtained with the code TRECO (see previous section) are presented. All of the results were obtained using the AP7 model which was obtained by Lavine and Vette¹⁴ using experimental data taken over the period 1961 to 1966 and which is recommended for proton energies > 50 MeV. The magnetic field representation used was the 120-term spherical harmonic expansion of Cain

et al. 19 All of the spectra presented here extend from 30 MeV to 1000 MeV. The use of the AP7 model in the 30- to 50-MeV region is an approximation in that the AP1 model is recommended for these energies. The AP7 model is used here below 50 MeV to avoid a discontinuity at 50 MeV that exists between the AP1 and AP7 models. The use of AP7 below 50 MeV leads to a slight overestimate of the differential proton flux below 50 MeV. The proton flux, of course, is not zero at energies < 30 MeV, but the magnitude of the flux at the lower energies is of no interest here because protons with energies < 30 MeV will be stopped by the thinnest shield considered in this report. The assumption is made here that all Van Allen belt proton spectra are zero above 1000 MeV. This choice of 1000 MeV as the energy above which there are no protons trapped in the earth's magnetic field is largely arbitrary. The assumption of a zero proton flux above 1000 MeV is made because of the lack of data at the higher energies and not because it is thought that there can be no trapped particles at energies > 1000 MeV.

The omnidirectional differential proton fluxes (normalized to unity) for circular orbits at various altitudes and with 0° inclination to the equatorial plane are shown in Fig. 2.4 as a function of energy. Similar fluxes are shown in Figs. 2.5 to 2.7 for orbital inclinations of 30°, 60°, and 90°, respectively. The results shown in Figs. 2.4 to 2.7 were obtained by averaging over a time of one day. Lavine and Vette have published data analogous to those shown in Figs. 2.4 to 2.7 obtained with an averaging time of two days. Comparisons of the two sets of data indicate that the

^{19.} J. C. Cain, S. J. Hendricks, R. A. Langel, and W. V. Hudson, "A Proposed Model for the International Geomagnetic Reference Field - 1965," J. Geomag. Geoelect. 19, 335 (1967).

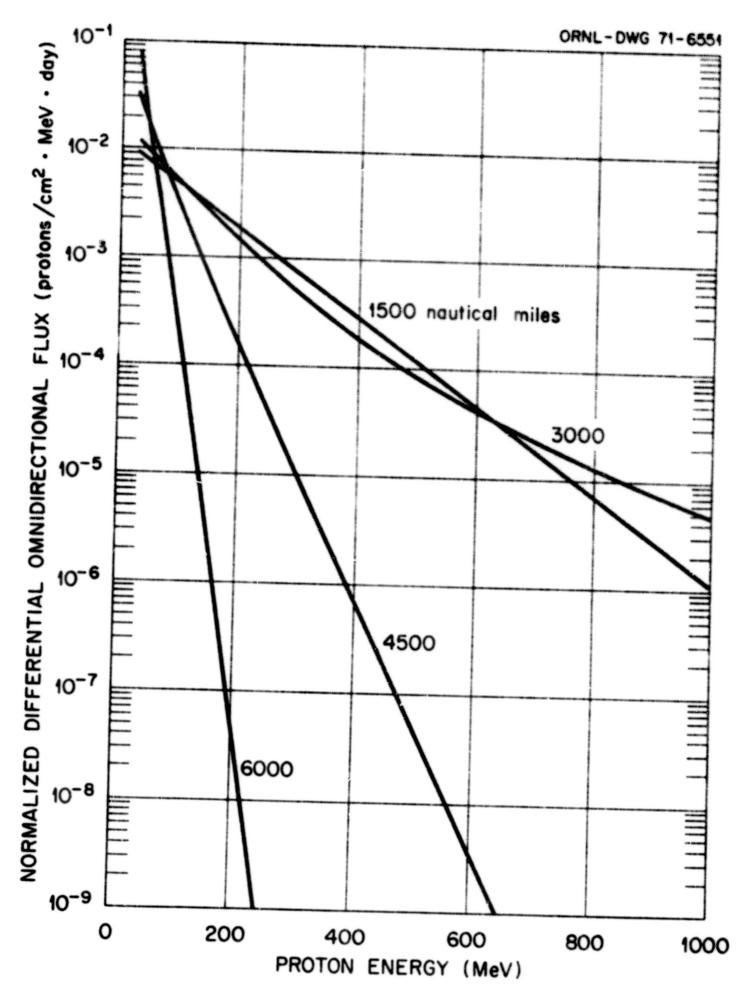


Fig. 2.4. The differential proton flux in the Van Allen belt for circular orbits at 0° equatorial inclination and at several altitudes. All fluxes are normalized to 1 proton/cm² •day with energies > 30 MeV.

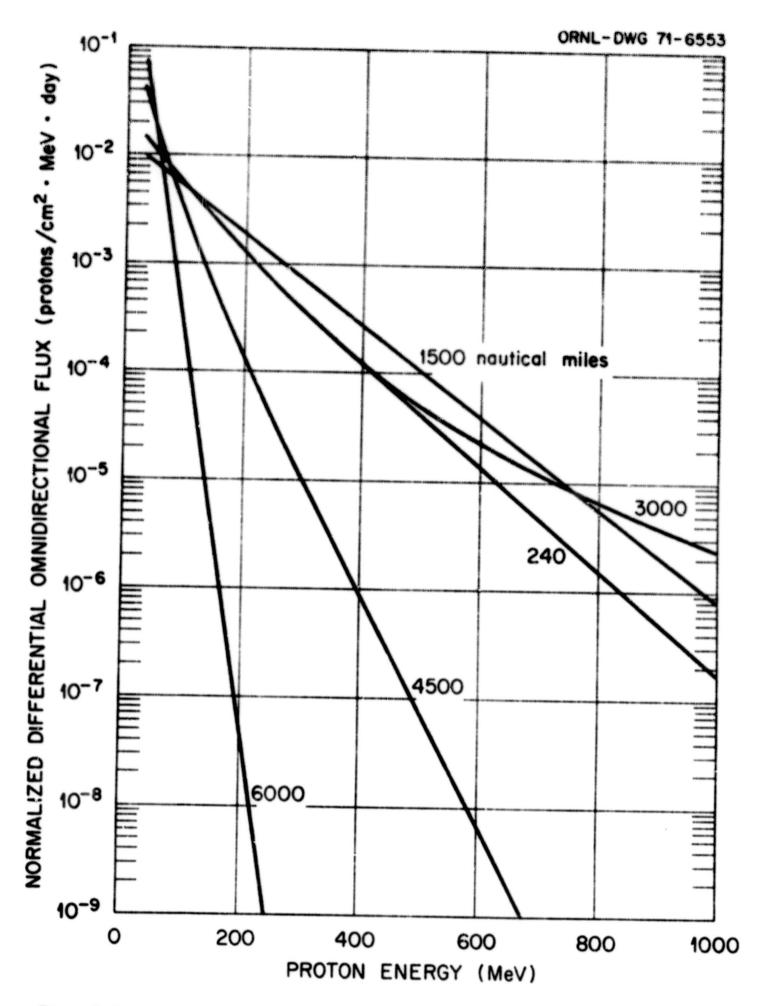


Fig. 2.5. The differential proton flux in the Van Allen belt for circular orbits at 30° equatorial inclination and at several altitudes. All fluxes are normalized to 1 proton/cm² day with energies > 30 MeV.

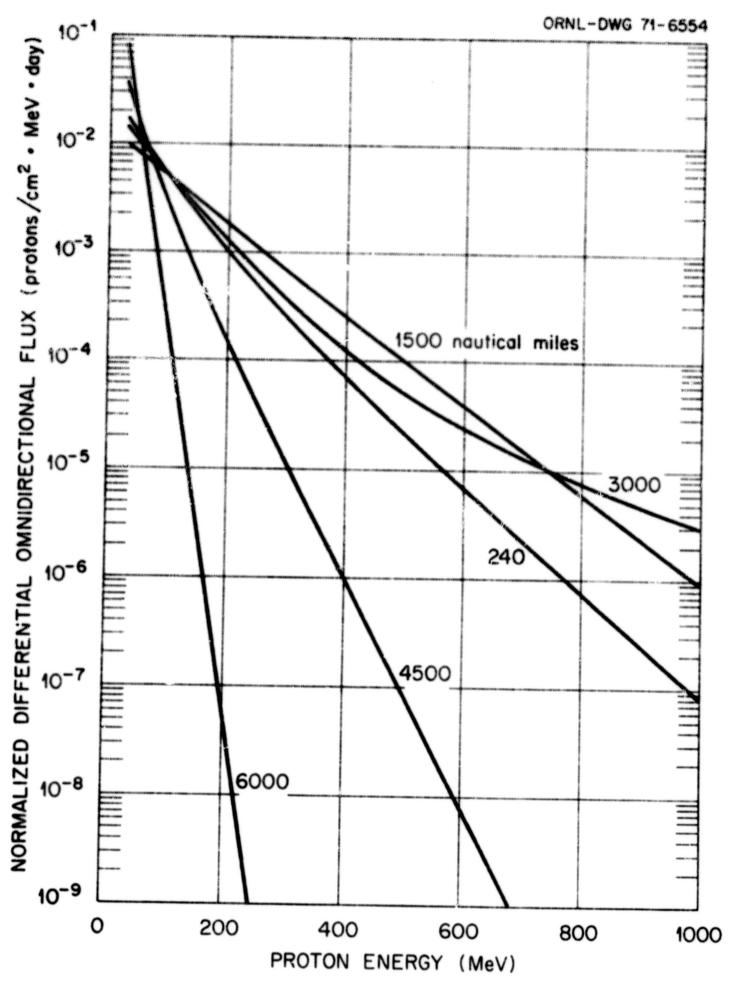


Fig. 2.6. The differential proton flux in the Van Allen belt for circular orbits at 60° equatorial inclination and at several altitudes. All fluxes are normalized to 1 proton/cm²•day with energies > 30 MeV.

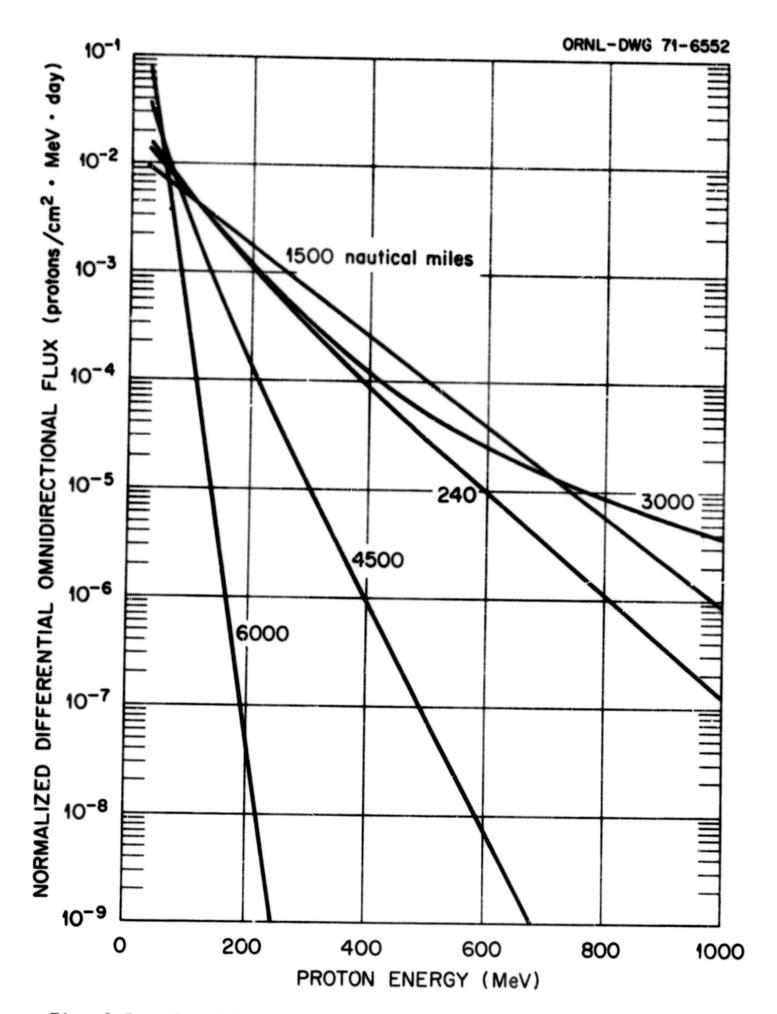


Fig. 2.7. The differential proton flux in the Van Allen belt for circular orbits at 90° equatorial inclination and at several altitudes. All fluxes are normalized to 1 proton/cm² •day with energies > 30 MeV.

differential proton fluxes based on a one-day average usually are not significantly different from the differential proton fluxes based on a two-day average, but this is not true for all possible orbits.

All of the differential proton fluxes shown in Figs. 2.4 to 2.7 have been normalized for comparison purposes to 1 proton cm⁻² day⁻¹ with energy > 30 MeV. The normalization factors for each of the cases shown in Figs. 2.4 to 2.7 are given in Table 2.1. From a comparison of the curves in each figure, it is evident that the spectral shape is very dependent on the altitude of the orbit.

The omnidirectional differential proton flux is shown in Fig. 2.8 as a function of energy for circular orbits of various equatorial inclinations and an altitude of 240 nautical miles. Similar results for altitudes of 1500, 3000, 4500, and 6000 nautical miles are shown in Figs. 2.9 to 2.12. The data presented in Figs. 2.8 to 2.12 are the same as those presented in Figs. 2.4 to 2.7 except that they have been multiplied by the normalization factors given in Table 2.1. Comparison of the curves in each figure indicates that the shape of the proton flux per unit energy is not strongly dependent on the orbital inclination. The differential fluxes in Figs. 2.8 to 2.12 were used in the shielding calculations discussed later in this report.

TABLE 2.1

Total Omnidirectional Proton Flux with Energies > 30 MeV for Circular Orbits Averaged Over One Day

	Omnidirectional Flux (protons/cm ² •day)				
Altitude		Inclination			
(nautical miles)	0°	30°	60°	90°	
240	0	2.55×10^{6}	1.42 × 10 ⁶	1.26 × 10 ⁶	
1500	1.44×10^9	7.00×10^{8}	3.49×10^{8}	3.00 × 10 ⁸	
3000	2.25×10^{8}	9.79×10^{7}	5.11×10^{7}	4.37 × 10 ⁷	
4500	2.83×10^{7}	1.21×10^{7}	6.07×10^{6}	5.24 × 10 ⁶	
6000	5.87 × 10 ⁵	2.06×10^{5}	1.11×10^{5}	9.11 × 10 ⁴	

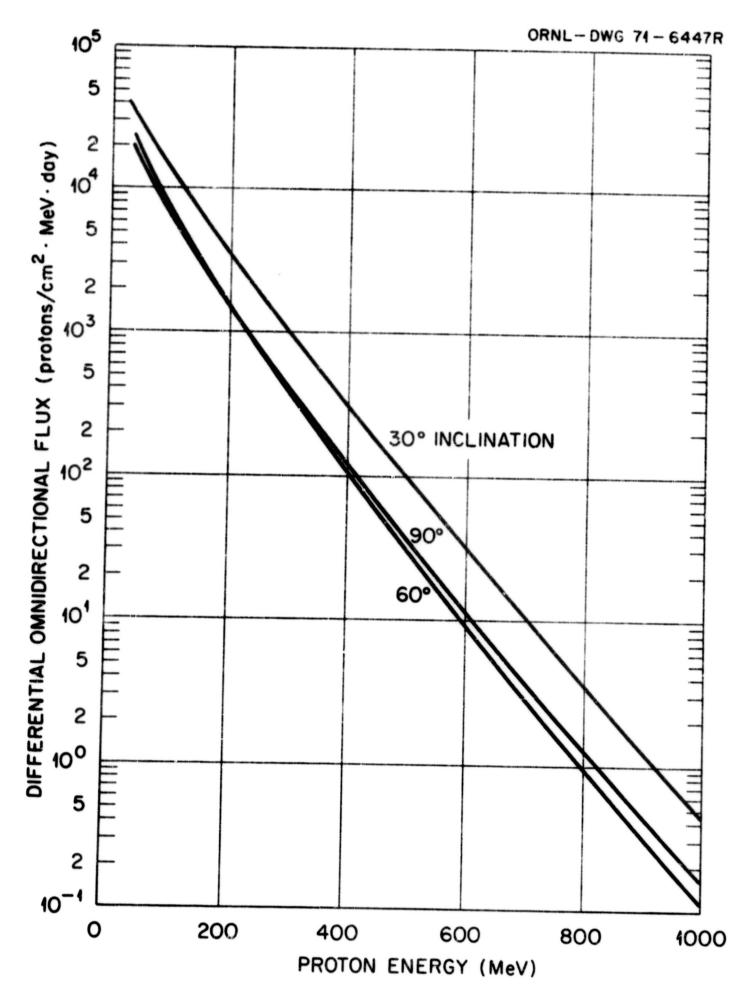


Fig. 2.8. The differential proton flux in the Van Allen belt for circular orbits with several inclinations at an altitude of 240 nautical miles.

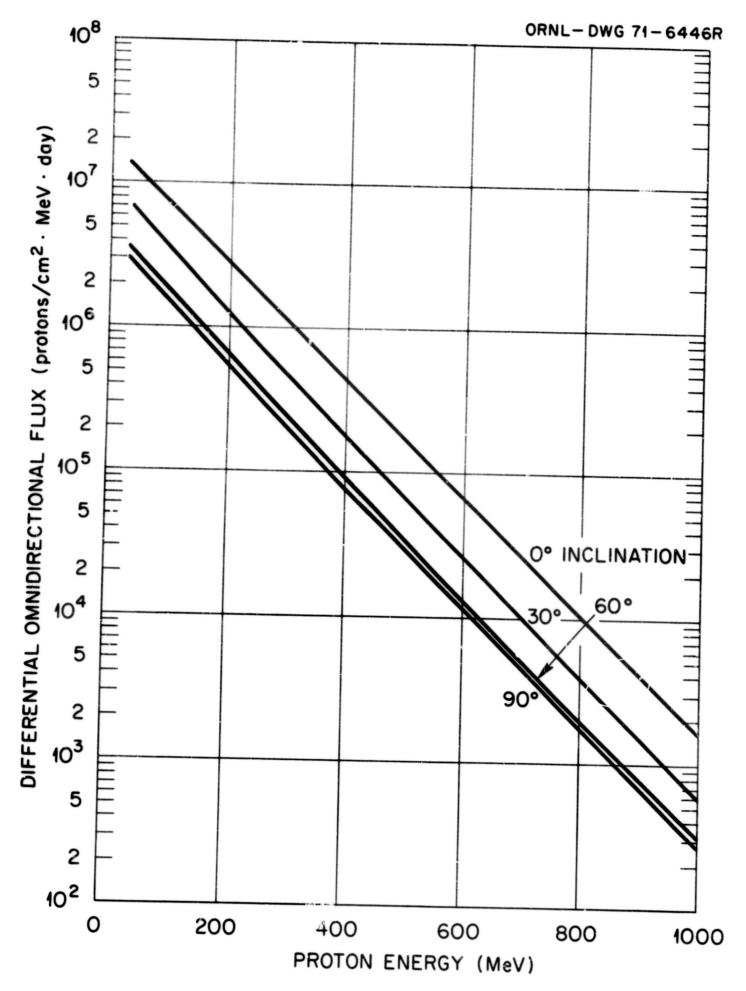


Fig. 2.9. The differential proton flux in the Van Allen belt for circular orbits with several inclinations at an altitude of 1500 nautical miles.

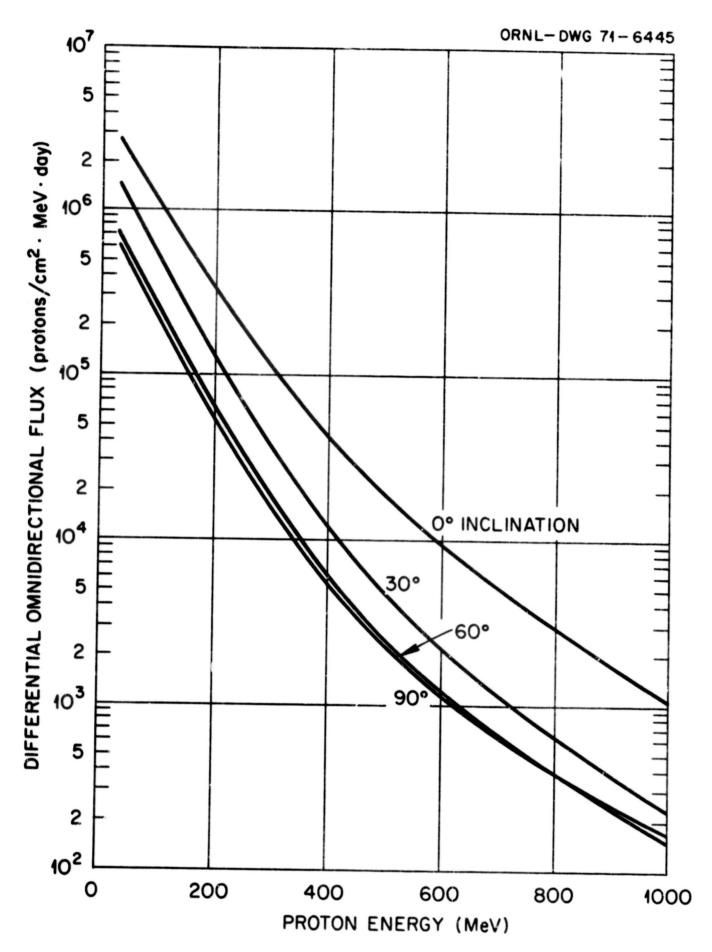


Fig. 2.10. The differential proton flux in the Van Allen belt for circular orbits with several inclinations at an altitude of 3000 nautical miles.

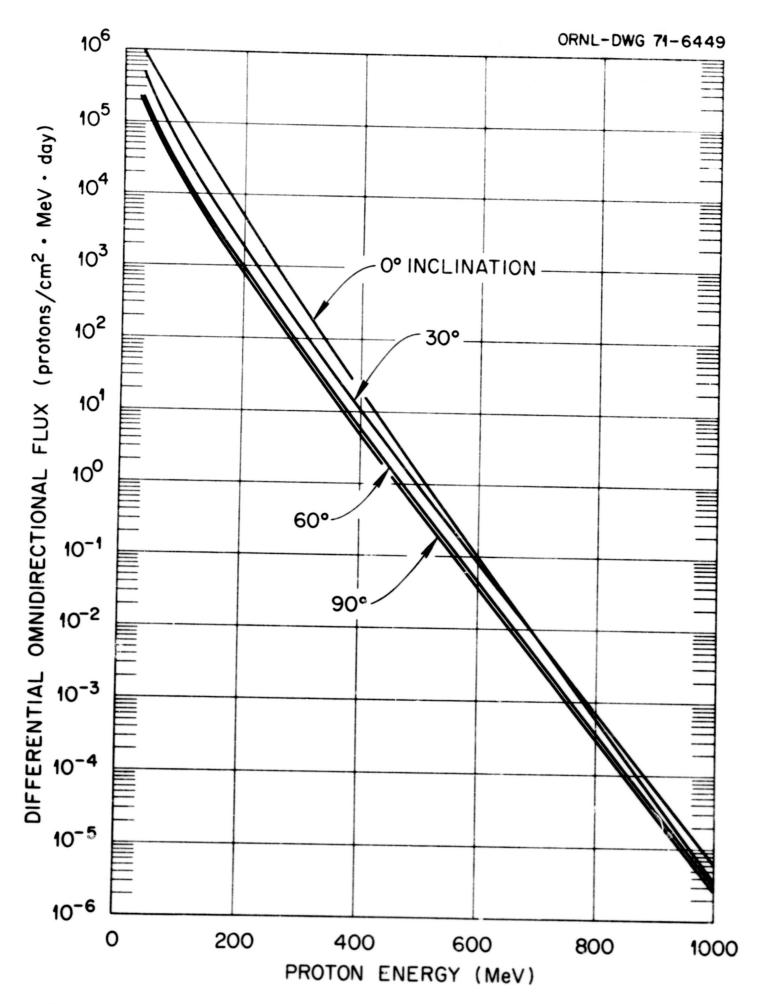


Fig. 2.11. The differential proton flux in the Van Allen belt for circular orbits with several inclinations at an altitude of 4500 nautical miles.

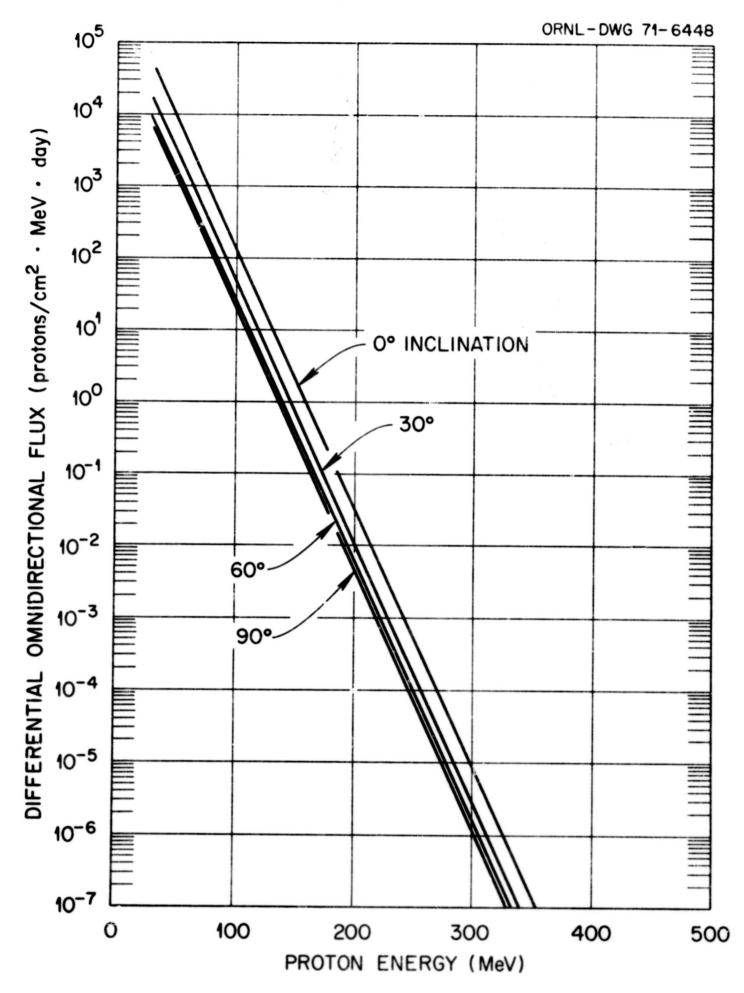


Fig. 2.12. The differential proton flux in the Van Allen belt for circular orbits with several inclinations at an altitude of 6000 nautical miles.

2.2 SOLAR-FLARE PROTON AND ALPHA-PARTICLE SPECTRA

The planning of spaceflight missions beyond the vicinity of the earth requires that the occupants and/or the equipment borne by the vehicle be adequately shielded against the charged-particle radiation from solar flares. The radiation emitted by some flares presents a significant hazard in spaceflight missions, and extensive studies have been made of the radiation associated with solar flares.²⁰⁻²⁷

- 22. K. A. Anderson, "Ionizing Radiation Associated with Solar Radio Noise Storm," Phys. Rev. Letters 1, 335 (1958).
- 23. W. I. Axford and G. C. Reid, "Increases in Intensity of Solar Cosmic Rays Before Sudden Commencements of Geomagnetic Storms," J. Geophys. Res. 68, 1793 (1963).
- 24. F. B. McDonald, "Review of Galactic and Solar Cosmic Rays," Proc. Second Symposium Protection Against Radiation in Space, Gatlinburg, Tennessee, October 12-14, 1964, NASA SP-71, 1964, p. 19.
- 25. J. L. Modisette, T. M. Venson, and A. C. Hardy, "Model Solar Proton Environments for Manned Space Design," Tech. Note NASA-TN-D-2746, 1965.
- 26. C. Y. Fan, M. Pick, R. Pyle, J. A. Simpson, and D. R. Smith, "Protons Associated with Centers of Solar Activity and their Propogation in Interplanetary Magnetic Field Regions Corotating with the Sun," J. Geophys. Res. 73, 1555 (1968).
- 27. L. J. Lanzerotti, "Solar Flare Particle Radiation," Proc. of the National Symposium on Natural and Manmade Radiation in Space, Las Vegas, Nevada, March 1-5, 1971, NASA TM X-2440, p. 193.

^{20.} S. E. Forbush, "Three Unusual Cosmic Ray Increases Possibly Due to Charged Particles from the Sun," Phys. Rev. 70, 771 (1946).

^{21.} D. K. Bailey, "Disturbances in the Lower Ionosphere Observed at VHF Following the Solar Flare of 23 February 1956 with Particular Reference to Auroral-Zone Absorption," J. Geophys. Res. 62, 431 (1957).

In this section, the characteristics of solar-flare particulate radiation pertinent in shielding calculations are discussed. In particular, the charge composition and mathematical representations of flare energy spectra are presented.* Included also is a brief discussion of the prediction of solar-flare events necessary to estimate the hazardous radiation environments that might be encountered during a particular mission.

2.2.1 Charge Composition in Solar-Flare Radiation

Solar-flare particulate radiation is composed chiefly of protons with a varying number of alpha particles and an admixture of heavier ($Z \ge 3$) nuclei. The characteristic fractions of these charged particles vary widely from flare to flare, as well as within a given flare as a function of time.

Protons have been detected in all solar-flare particulate radiation, and the proton energy spectra and intensities have been investigated in considerable detail. 29-31 Compilations of the proton flux distributions measured at a distance one astronomical unit from the earth during solar cycle 19

^{*}The discussion here is restricted to the region outside of the earth's magnetosphere. Inside the magnetosphere, the solar-flare particle spectra are modified by the earth's magnetic field. Information on how these modifications may be taken into account at least approximately will be found in the work of Kuhn $et\ al.^{28}$ and Burrell $et\ al.^{15}$

^{28.} E. Kuhn, W. T. Payne, and F. E. Schwamb, "Solar Flare Hazard to Earth-Orbiting Vehicles," Republic Aviation Corp. Report RAC 1395-1, PCD-TR-64-12, 1964.

^{29.} K. A. Anderson, R. Arnoldy, R. Hoffman, L. Peterson, and J. R. Winkler, "Observations of Low Energy Solar Cosmic Rays from the Flare of 22 August 1968," J. Geophys. Res. 64, 1133 (1959).

^{30.} H. S. Ghielmetti, "The Spectrum and Propogation of Relativistic Solar Flare Particles During July 17-18, 1959," J. Geophys. Res. 66, 1611 (1961).

^{31.} E. C. Stone, "A Measurement of the Primary Proton Flux from 10 to 130 MeV," J. Geophys. Res. 69, 3939 (1964).

have been prepared by Webber³² and by Lewis *et al.*³³ Proton flux data for solar cycle 20 which began in approximately 1965 are not yet as well established as those for solar cycle 19, but a discussion of and references to the available data will be found in the work of Atwell³⁴ and of Armstrong and Alsmiller.³⁵

The alpha-particle component observed in solar-flare radiation has also been studied extensively. 24,36-40 Malitson and Webber 1 observed that the proton-to-alpha-particle ratios vary from ~ 10 to ~ 100 above fixed particle energies. A comparison of the peak omnidirectional integral fluxes of protons and alpha particles observed in solar cycle 19 is given in Table 2.2.

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- 33. L. R. Lewis, G. M. Brown, J. Gabler, and R. M. Magee, "Solar Flare Radiation Survey," USAF Weapons Laboratory Report RTD-DTR-63-3044, 1963.
- 34. W. Atwell, "The Significant Solar Proton Events in the 20th Solar Cycle for the Period October 1964 to March 1970," Proc. National Symposium on Natural and Manmade Radiation in Space, Las Vegas, Nevada, March 1-5, 1971, NASA TM X-2440, p. 329.
- 35. T. W. Armstrong and R. G. Alsmiller, Jr., "Calculation of Cosmogenic Radionuclides in the Moon and Comparison with Apollo Measurements," Proc. Second Lunar Science Conference, Geochim. Cosmochim. Acta, Suppl. 2, Vol. 2, 1729 (1971).
- 36. S. Biswas, P. S. Frier, and W. Stein, "Solar Protons and Alpha Particles from the September 3, 1960, Flares," J. Geophys. Res. 67, 13 (1962).
- 37. E. P. Ney and W. A. Stein, "Solar Protons, Alpha Particles, and Heavy Nuclei in November, 1960," J. Geophys. Res. 67, 2087 (1962).
- 38. S. Biswas, C. E. Fitchel, D. E. Guss, and C. J. Waddington, "Hydrogen, Helium, and Heavy Nuclei from the Solar Event on November 15, 1960," J. Geophys. Res. 68, 3109 (1963).
- 39. G. R. Yates, "Solar Flare High Energy Alpha Particles and Their Storage in Interplanetary Space," J. Geophys. Res. <u>69</u>, 3077 (1964).
- 40. N. C. Durgaprasad, C. E. Fitchel, D. E. Guss, and D. V. Reames, "Nuclear-Charge Spectra and Energy Spectra in the September 2, 1966 Solar Particle Event," Astrophys. J. 154, 307 (1968).
- 41. "Solar Proton Manual," Frank B. McDonald, Ed., Goddard Space Flight Center Report NASA TR R-169, 1963, Chapter 1, p. 1.

^{32.} W. R. Webber, "An Evaluation of the Radiation Hazard Due to Solar Proton Events," Boeing Report D2-90469, 1963.

TABLE 2.2^a

Peak Omnidirectional Flux (Particles/cm²•sec) for
Nine Large Solar Events

	Protons			Alpha Particles		
Event	> 10 MeV	> 30 MeV	> 100 MeV	> 40 MeV	> 120 MeV	> 400 MeV
3/23/58	8,000	1,200	100	420	60	1.2
5/10/59	30,000	6,000	1,000	5,000	500	. * 5
7/10/59	15,000	4,000	1,200	800	160	5
7/14/59	50,000	10,000	1,200	10,000	1,000	10
7/16/59	18,000	6,000	1,500	5,000	1,500	100
9/30/60	450	200	60	6	3	0.4
11/12/60	32,000	12,000	2,500	4,000	1,500	180
11/15/60	22,000	8,000	2,400	4,200	1,500	160
7/18/61	7,000	2,500	60	280	100	11
TOTAL	182,450	49,900	10,020	29,706	6,323	472.6

a. Taken from Ref. 2.

The peak flux is the largest value of the flux observed during the life of the flare. The time-integrated proton and alpha-particle fluxes above specific kinetic energies, $J_{p}(>E)$ and $J_{\alpha}(>E)$, respectively, are given in Table 2.3. The last column shows

$$\frac{J_{p}(>30)}{J_{\alpha}(>120)}$$

for those flares for which both radiation components were observed.

The heavy-nuclei component in solar-flare radiation has been studied by Fitchel and Guss⁴² and by Ney and Stein.³⁷ The carbon-nitrogen-oxygen (CNO) group appears to comprise the major portion of the heavy particles that combine to constitute about 0.1% of the total flare radiation.

In this report, only the proton and alpha-particle components and the shielding against these radiations will be discussed.

2.2.2 Energy Spectra of Solar-Flare Radiation

The intensity, energy spectra, and angular distribution of solar-flare particles vary widely from event to event and as a function of time during an event. The duration of a flare is of the order of a day. For most shielding purposes, it is sufficient to consider only the time-integrated effect of the flare, so only the time-integrated flare spectra will be considered here.

During the early stage of a flare, the particle angular distribution is quite anisotropic, but the distribution rather rapidly tends toward isotropy and is isotropic during most of the life of the event. A discussion of flare anisotropies may be found in the report by McCracken. Throughout this report, it will be assumed that the time-integrated flare spectra are isotropic.

^{42.} C. E. Fitchel and D. E. Guss, "Heavy Nuclei in Solar Cosmic Rays," Phys. Rev. Letters 6, 495 (1961).

^{43. &}quot;Solar Proton Manual," Frank B. McDonald, Ed., Goddard Space Flight Center Report NASA TR R-169, 1963, Chapter 3, p. 57.

TABLE 2.3 $\begin{tabular}{ll} Time-Integrated Omnidirectional Flux of Protons and Alpha Particles a \\ & (Particles/cm^2) \end{tabular}$

	J _p (> E)		J _α (J (> 30 MeV)	
Event	E > 30 MeV	E > 100 MeV	E > 120 MeV	E > 400 MeV	$\int_{\alpha}^{\overline{p}} J_{\alpha}(> 120 \text{ MeV})$
2/23/56	1.0 × 10 ⁹	3.5 × 10 ⁸	7 × 10 ⁶	8 × 10 ⁴	70
1/20/57	2.0×10^8	7.0×10^6			
10/20/57	5.0×10^7	1.0×10^{7}			
3/23/58	2.5×10^{8}	1.0×10^{7}			
7/7/58	2.5×10^{8}	9.0×10^{6}			
8/16/58	4.0×10^{7}	1.6 × 10 ⁶			
8/22/58	7.0×10^7	1.8×10^{6}			
5/10/59	9.6×10^{8}	8.5×10^7	4.2×10^{7}	3.5×10^5	22.8
7/10/59	1.0 × 10 ⁹	1.4 × 10 ⁸	2.4×10^{7}	5 × 10 ⁵	41.7
7/14/59	1.3×10^9	1.0 × 10 ⁸	8.0×10^7	7×10^5	16.2
4/1/60	5.0×10^6	8.5 × 10 ⁵			
5/4/60	6.0×10^{6}	1.2 × 10 ⁶			
9/3/60	3.5×10^{7}	7.0×10^6	3.6×10^5	4 × 10 ⁴	97
11/12/60	1.3×10^9	2.5 × 10 ⁸	1.2×10^{8}	1.1 × 10 ⁷	10.8
11/15/60	7.2×10^8	1.2 × 10 ⁸	9 × 10 ⁷	6.5 × 10 ⁶	8
7/18/61	3.0×10^8	4.0 × 10 ⁷	5.5×10^6	4.0 × 10 ⁵	54.5
10/23/62	1.2×10^5	1.0 × 10 ⁴			

a. Taken from Ref. 2 and from Ref. 15.

Time-integrated solar-flare energy spectra may be represented by power functions of kinetic energy or magnetic rigidity or as exponential functions of magnetic rigidity. The magnetic rigidity $P_{\mbox{j}}$ is defined by

$$P_{j} = \frac{P_{j}c}{z_{j}e}$$
, $j = p, \alpha$, (2.5)

where

p; = the particle momentum,

c = the velocity of light,

 z_j = the charge number (z_p = 1, z_α = 2),

e = the electronic charge.

It has been demonstrated by Hseih⁴⁴ and others⁴⁵ that for the lower energies (< 30 MeV) expressing a solar flare with a power function in energy leads to an overestimate of the flux, while an exponential-in-rigidity formulation generally underestimates the number of particles. At the higher energies (E > 200 MeV), the reverse is true. Modisette⁴⁶ and Webber⁴⁷ have reviewed the methods of flare-spectra representation and have concluded that it is preferable to express integral solar-flare spectra using exponential-in-rigidity functions. Lanzerotti⁴⁸ has also compared the exponential-in-rigidity representation with the power law in energy representation. It is now generally accepted that the exponential-in-rigidity form gives reasonable representation of the time-integrated solar-flare data, and this representation

^{44.} R. C. Hseih, University of Chicago, private communication, 1970.

^{45.} NASA TR R-169, op. cit., Chapters 1 and 2.

^{46.} J. Modisette, Manned Spacecraft Center, NASA, private communication, 1963.

^{47.} W. R. Webber, University of Minnesota, private communication, 1963.

^{48.} L. J. Lanzerotti, World Data Center A, 56, Research Laboratories, NOAA, Boulder, Colorado, Report UAG-5, 1969. See also Ref. 27.

will be used throughout this report. The time-integrated omnidirectional flux, i.e., the omnidirectional fluence, of protons and alpha particles above a given kinetic energy is expressed as

$$J_{j}(>E) = J_{oj} \exp[-P_{j}(E)/P_{o}]$$
, $j = p,\alpha$, (2.6)

where

 J_j (>E) = the number of protons, or alpha particles, per unit area in the flare having kinetic energy > E,

 $P_{i}(E)$ = the rigidity defined by Eq. 2.5,

Joj, Po = the parameters that characterize a particular flare.

It is important to note that for a particular flare the same value of the parameter $P_{_{\scriptsize O}}$ is used in the proton and alpha-particle spectra.

Modisette et al. 25 have given values for the parameters J_{op} and P_{o} for a large number of flares. They found that P_{o} varies between 50 and 200 MV, * and the total number of protons with energies > 30 MeV varies from $\sim 10^6$ to $\sim 10^9$ protons/cm². Thus, these values roughly characterize the spectra that must be considered. For solar-flare events of cycle 19, the characteristic rigidities P_{o} and constants J_{op} are summarized in Table 2.4. The significant solar-flare events that occurred during solar cycles 19 and 20 are shown in Fig. 2.13. This figure is taken from Ref. 35 except that two flares in early 1970 have been added. 36 , 49 The arrows in the latter part of 1970 and the early part of 1971 indicate times when significant flare events for which data are not yet available are known to have occurred. 49 In general, solar

^{*}Rigidity is usually given in units MV (million volts). This unit is such that if P = x MV, then Pe = x MeV; i.e., Pe in MeV has the same numerical value as P in MV. The relation between rigidity, P, in MV and kinetic energy, E, in MeV is given in Eq. 2.8.

^{49.} J. H. King, Goddard Space Flight Center, Greenbelt, Maryland, private communication, 1972.

TABLE 2.4

Integral Proton Flux (Protons/cm²•Flare) Above 30 and 100 MeV with Corresponding Characteristic Rigidity P a

Date	J _p (>30MeV)	J _p (>100MeV)	P ₀ (M V)	J op
2/23/56	1.0×10^{9}	3.5×10^{8}	195	3.41×10^{3}
8/3/56	2.5×10^{7}	6.0×10^{6}	144	1.32×10^{8}
1/20/57	2.0×10^{8}	7.0×10^{6}	61	1.02×10^{10}
8/29/57	1.2×10^{8}	3.0×10^{6}	56	8.49×10^{9}
10/20/57	5.0×10^{7}	1.0×10^{7}	127	3.30×10^{8}
		_		
3/23/58	2.5×10^{8}	1.0×10^{7}	64	1.04×10^{10}
7/7/58	2.5×10^8	9.0×10^{6}	62	1.18×10^{10}
8/16/58	4.0×10^{7}	1.6×10^{6}	64	1.67×10^9
8/22/58	7.0×10^7	1.8×10^6	56	5.02×10^9
8/26/58	1.1×10^8	2.0×10^{6}	51	1.21×10^{10}
9/22/58	6.0×10^{6}	1.0×10^5	50	7.21×10^8
5/40/50	0.0408	0.5 407		4 05 10
5/10/59	9.6×10^{8}	8.5×10^{7}	84	1.67×10^{10}
7/10/59	1.0×10^9 1.3×10^9	1.4×10^8	104	1.00×10^{10}
7/14/59 7/16/59	9.1×10^8	$ \begin{array}{c c} 1.0 \times 10^8 \\ 1.3 \times 10^8 \end{array} $	80	2.59×10^{10}
1710/33	5.1 × 10	1.3 × 10	105	8.92×10^9
4/1/60	5.0×10^6	8.5×10^5	116	3.93×10^7
4/28/60	5.0×10^6	7.0×10^{5}	104	5.01×10^{7}
5/4/60	6.0×10^6	1.2×10^6	127	3.96×10^{7}
5/13/60	4.0×10^{6}	4.5×10^5	94	5.09×10^{7}
9/3/60	3.5×10^{7}	7.0×10^{6}	127	2.31×10^{8}
9/26/60	2.0×10^{6}	1.2×10^{5}	73	5.29×10^{7}
11/12/60	1.3×10^{9}	2.5×10^{8}	124	8.98×10^9
11/15/60	7.2×10^8	1.2×10^8	114	5.89×10^9
11/20/60	4.5×10^7	8.0×10^6	118	3.44×10^{8}
			"	0.44 \ 10
7/11/61	3.0×10^{6}	2.4×10^{5}	81	5.77×10^7
7/12/61	4.0×10^7	1.0×10^{6}	56	2.83×10^9
7/18/61	3.0×10^{8}	4.0×10^{7}	102	3.13×10^{9}
7/20/61	5.0×10^{6}	9.0×10^{5}	120	3.66×10^{7}
9/28/61	6.0×10^{6}	1.1×10^{6}	121	4.33×10^{7}
10/00/00				
10/23/62	1.2×10^{5}	1.0×10^4	83	2.13×10^{7}

a. Taken from Ref. 15.

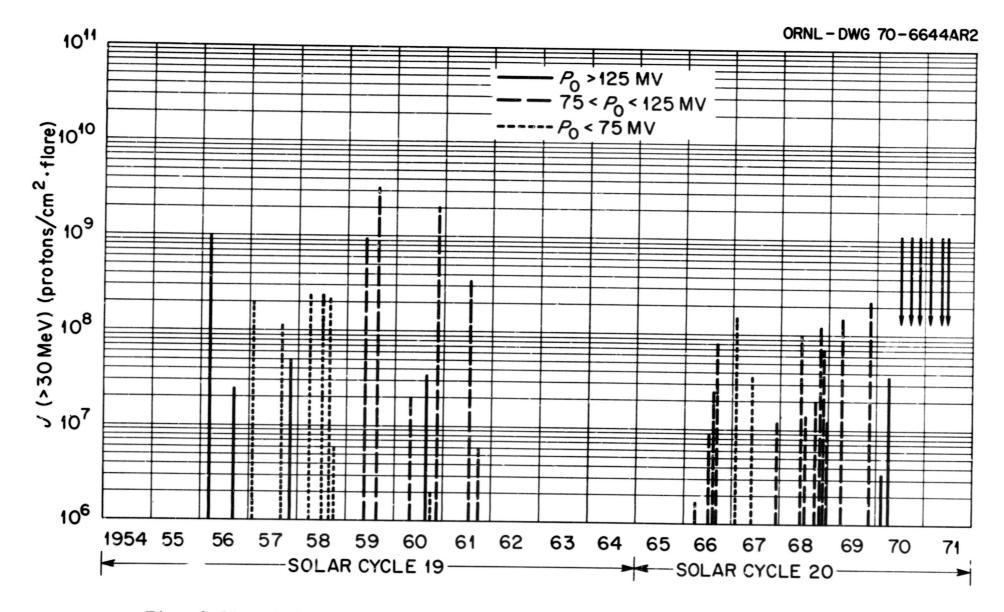


Fig. 2.13. Solar proton intensity during solar cycle 19 and the first part of solar cycle 20.

cycle 20 has been less intense than solar cycle 19 and there are indications that solar cycle 19 may have been anomolously large, but this is by no means certain.

The differential energy spectrum of the particles in a flare may be obtained by differentiating Eq. 2.6 with respect to energy. Thus, one has

$$-\frac{\mathrm{dJ}_{j}(>E)}{\mathrm{dE}} = \frac{\mathrm{J}_{oj}}{\mathrm{P}_{o}} \exp \left[-\frac{\mathrm{P}_{j}(E)}{\mathrm{P}_{o}}\right] \frac{\mathrm{dP}_{j}}{\mathrm{dE}}, \qquad j = p, \alpha \qquad (2.7)$$

If Eq. 2.5 is written in the form

$$P_{j}(E) = \frac{1}{z_{j}} \sqrt{E^{2} + 2M_{j}E}$$
, (2.8)

where

 $P_{j}(E)$ = the magnetic rigidity in units of MV,

E = the particle kinetic energy in MeV,

 M_{j} = the rest energy in MeV of particles of type j,

then

$$\frac{dP_{j}}{dE} = \frac{1}{z_{j}} \frac{E + M_{j}}{\sqrt{E^{2} + 2M_{j}E}},$$
 (2.9)

and for the differential energy spectrum Eq. 2.7 becomes

$$-\frac{dJ_{j}(>E)}{dE} = \frac{J_{oj}}{z_{j}P_{o}} \frac{E + M_{j}}{\sqrt{E^{2} + 2M_{j}E}} \exp \left[-\frac{\sqrt{E^{2} + 2M_{j}E}}{z_{j}P_{o}}\right], \quad j = p,\alpha \quad . \quad (2.10)$$

Values of the magnetic rigidity $P_{j}(E)$ as a function of particle kinetic energy obtained from Eq. 2.8 are shown in Fig. 2.14.

The highest energy for which Eq. 2.10 gives a reliable representation of solar-flare proton and alpha-particle spectra is not well established and probably depends to some extent on the characteristic rigidity of the flare. In this report, the somewhat arbitrary assumption is made that the

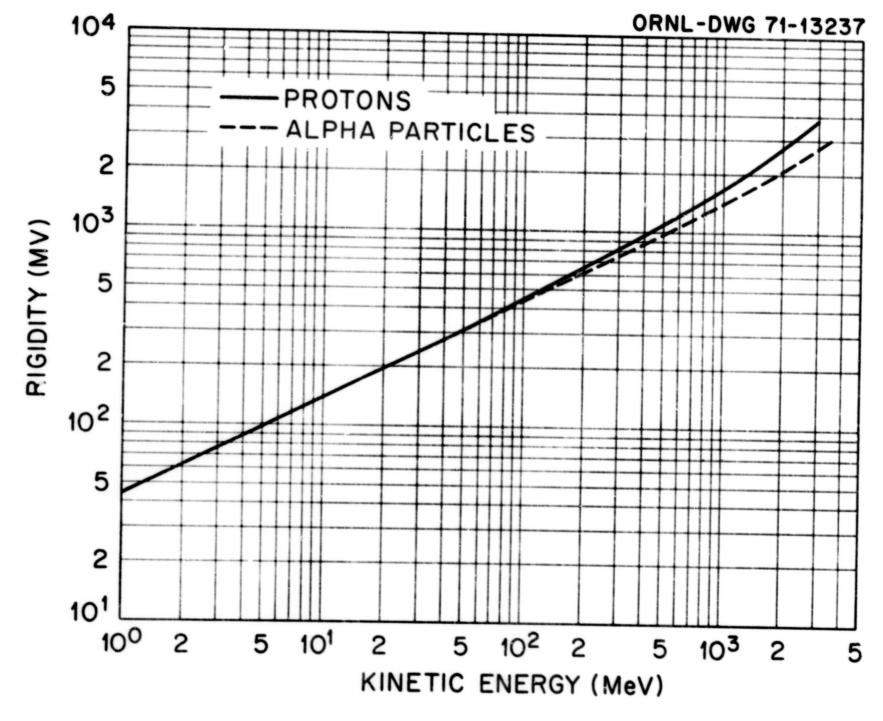


Fig. 2.14. Relationship between kinetic energy and magnetic rigidity.

differential fluence of both protons and alpha particles for all flares may be represented by Eq. 2.10 for energies < 3000 MeV and may be taken to be zero at energies above 3000 MeV. Proton and alpha-particle energy spectra for characteristic rigidities of 50, 100, and 200 MV are shown as a function of energy in Fig. 2.15. For convenience, the spectra have been normalized to 10^9 particles per cm² with energies between 30 and 3000 MeV; i.e., Joj has been determined by the equation

$$J_{oj} = \frac{10^{9}}{\frac{1}{z_{j}^{2}P_{o}} \int_{E_{min}}^{E_{max}} \frac{E + M_{j}}{P_{j}(E)} \exp \left[-\frac{P_{j}(E)}{P_{o}}\right] dE},$$
 (2.11)

where $E_{max} = 3000$ MeV and $E_{min} = 30$ MeV. Differential fluences such as those shown in Fig. 2.15 will be used in the shielding calculations discussed later in this report.

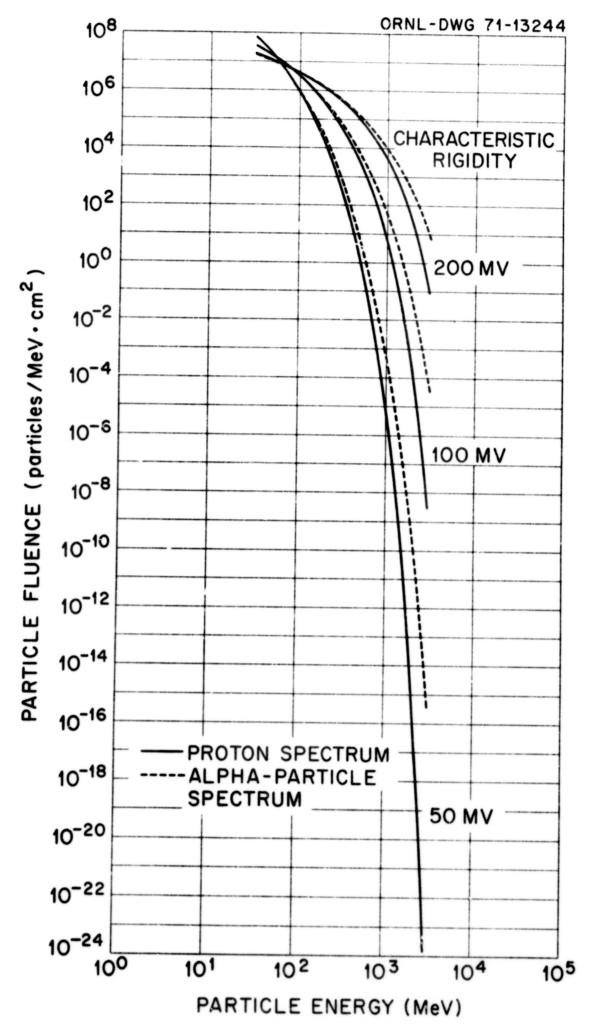


Fig. 2.15. Solar-flare proton and alpha-particle spectra of characteristic rigidities of 50, 100, and 200 MV.

2.2.3 The Probability of Solar-Flare Particle Emission During Spaceflights of Given Duration

In planning spaceflight missions outside of the earth's magnetic field, consideration must be given to the potential radiation hazards from the high-energy particles emitted from the sun during a solar flare. Since solar flares occur on a nearly random basis, mission planners must estimate the probability that solar-flare particle emission will occur during a flight and must estimate the radiation hazard to astronauts from this particle emission.

Detailed studies for estimating the probabilities of solar-flare occurrences and the particle energy spectra associated with these events have been made by Modisette et al., 50 Norman, 51 Lahti et al., 52 Yucker, 53 and Burrell. 54 The methods considered by the various authors contain many similarities, but they differ widely in detail, and there is considerable disparity in the results obtained. No attempt will be made here to enumerate the differences and subtleties of the various approaches, but rather the more

^{50.} J. L. Modisette, T. M. Vinson, and A. C. Hardy, "Model Solar Proton Environments for Manned Spacecraft Design," NASA-TN-D 2746, 1965.

^{51.} J. E. Norman, "Estimation of Radiation Hazard Probabilities Due to Solar Proton Events During the Maximum Solar Cycle Phase," Brown Engineering Report SSL-27548-1, 1967.

^{52.} G. P. Lahti, I. M. Karp, and B. M. Rosenbaum, "MCFLARE, a Monte Carlo Code to Simulate Solar Flare Events and Estimate Probable Doses Encountered on Interplanetary Missions," NASA TN D-4311, 1968.

^{53.} W. R. Yucker, "Statistical Analysis of Solar Cosmic-Ray Proton Dose," McDonnell Douglas Report MDC G-0363, 1970.

^{54.} M. O. Burrell, "The Risk of Solar Proton Events to Space Missions," Proc. National Symposium on Natural and Manmade Radiation in Space, Las Vegas, Nevada, March 1-5, 1971, NASA TM X-2440, 1972, p. 310; see also M. O. Burrell, "The Risk of Solar Proton Events to Space Missions," NASA TN D-6379, 1971.

straightforward considerations that are more or less common to all of the methods will be described. It is to be understood that the discussion here is primarily for illustrative purposes. For definitive information, Refs. 50 to 54 should be consulted.

The establishment of any model for arriving at the probability of solar-event occurrence is complicated by the insufficient data currently available on the history of radiation-producing flares. Solar flares follow an approximate 11-year cycle, and they achieve maximum intensity and frequency near the middle of this cycle. Some of the significant events that occurred during solar cycles 19 and 20 are shown in Fig. 2.13.³⁵ Other similar data will be found in Refs. 50 to 54 and in the references given therein.

If the available data for solar cycles 19 and 20 are arranged into a single composite solar-maximum cycle, a probability distribution in total particle fluence for a given mission may be obtained in the following manner. The launch data for a mission of given duration are selected at random during the composite cycle and the total fluence for the mission is obtained by adding the fluences of all events that occur during the mission. This process is repeated for a large number of mission histories, and the cumulative probability distribution of total mission fluences is constructed. An example of such a distribution for a mission length of one week and for the total mission fluence > 30 MeV is shown in Fig. 2.16.53 The straight line in the figure is a least-square fit to the data points. Note that since probability paper is used, the straight line represents a normal distribution in the logarithm of the fluence. In forming the distribution shown, only those histories of missions that encountered protons were used. The linest in the figure gives the probability of encountering protons during a

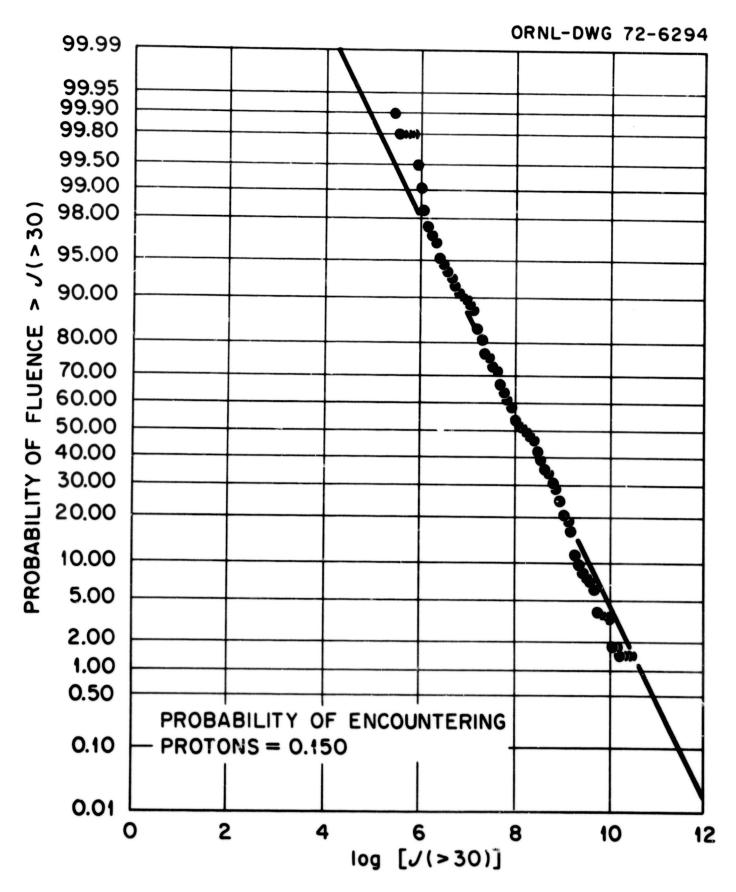


Fig. 2.16. Cumulative distribution of fluence above 30 MeV for 7-day mission during solar maximum.

mission. The probability that a mission fluence greater than J(>30 MeV) protons/cm² will be encountered during the one-week mission is obtained by multiplying the probability of encountering any protons by the probability that the mission fluence will be greater than J(>30 MeV).

As the mission duration increases, it should be noted that the selection process mentioned above gives many mission histories having approximately the same mission fluence, and therefore the probability distributions such as that shown in Fig. 2.16 are not as well determined in the case of long missions as in the case of short missions. For missions of the order of or less than six months, a straight-line fit to the data such as that shown in Fig. 2.16 is usually assumed since this is consistent with the data for short missions. For longer missions, the method becomes inapplicable, and more elaborate procedures are required. 53,54

With probability distributions such as that shown in Fig. 2.16, the mission fluence with E > 30 MeV may be obtained as a function of mission length for a given probability level. An example of such data taken from Ref. 50 is shown in Fig. 2.17. It should be recognized that extreme probability levels are very speculative and that the 99% level may well be the maximum that is credible since there is a fairly wide disagreement about this level. 54

Yucker 53 has considered the characteristic rigidities of known solar-flare events and has determined the cumulative probability of obtaining a flare with rigidity P_o as a function of P_o . Yucker's results are shown in Fig. 2.18. The solid line is a least-square fit to the data points and corresponds to the distribution

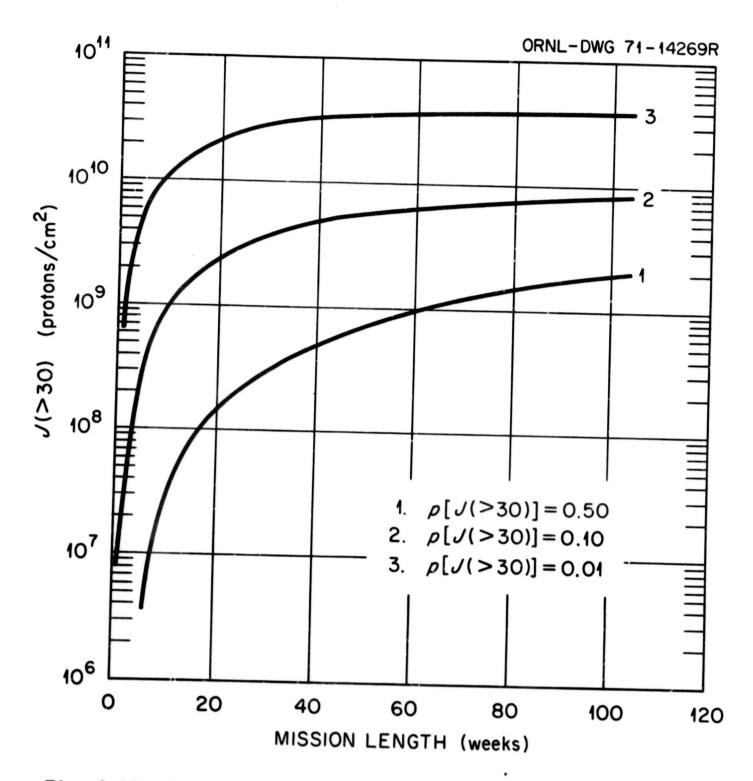


Fig. 2.17. Proton fluence with E > 30 MeV as a function of mission length for several probability levels.

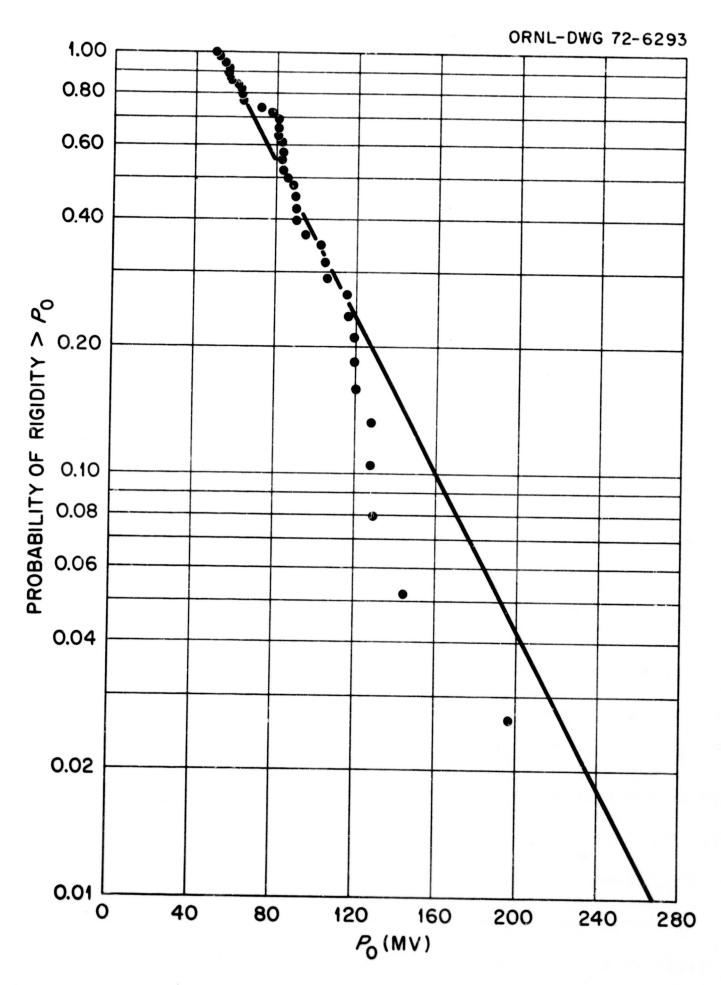


Fig. 2.18. Cumulative rigidity distribution of solar cosmic-ray proton spectra.

$$p(>P_0) = a exp(-b P_0)$$
,

where

a = 3.14

 $b - 0.0217 (MV)^{-1}$.

To determine the dose* from a solar flare, it is necessary to know the intensity and energy spectrum of the particles that are incident on the shield. If the representation of the flare spectrum discussed in Section 2.2.2 is used, it is necessary to know the number of particles per cm2 with energy > 30 MeV and the characteristic rigidity of the flare. To obtain the probability that a specific dose will not be exceeded on a mission of given duration, the data in Fig. 2.18 must be combined with data of the type given in Fig. 2.16 and the cumulative dose probability distribution must be calculated. The simplest procedure for carrying out this type of calculation is due to Modisette et $\alpha l.$ 50 These authors use the distribution in P_o, such as that determined from Fig. 2.18, to obtain an average P and then use this average value in all dose calculations. With P_{Ω} determined, doses may be calculated for various fluence levels, and the probabilities that these doses will be exceeded during a mission of given duration may be obtained directly from data of the type shown in Fig. 2.16 for the specified mission duration. more elaborate method for obtaining the incident flare spectrum corresponding to a given probability level is described in Ref. 54.

It should also be mentioned that several investigators prefer to work entirely in terms of dose probabilities and do not attempt to determine the incident spectrum. The procedure followed in this case is to calculate the dose for a given spacecraft geometry for each of the flares that appear in

^{*}See Sections 3.1 and 3.3.

the composite solar cycle used above. With these dose data and the information on flare occurrence used above, a cumulative dose distribution may be constructed by the same procedure that was used in obtaining the data points in Fig. 2.16. This procedure has the advantage of giving directly the desired probability that the dose on a mission of specified duration will exceed a given amount, but it has the disadvantage that the spacecraft geometry must be specified at the outset and the entire calculation must be repeated if this geometry is modified.

2.3 GALACTIC COSMIC RAYS

Galactic cosmic rays have been studied for many years and there is voluminous literature on the subject.* For shielding purposes, however, only a few general properties of these cosmic rays are of interest and only these properties are discussed here.

alpha particles, and 1% heavier nuclei, and have an energy spectrum which decreases rapidly with increasing energy but which extends to very high energies. For practical purposes, their angular distribution may be taken to be isotropic outside of the magnetosphere. The omnidirectional fluxes of protons and alpha particles with kinetic energy greater than E per nucleon are plotted in Fig. 2.19 as a function of E divided by the number of nucleons in a given species. The solar-minimum proton spectrum in Fig. 2.19 is taken from the review of McDonald⁵⁵ and the solar-maximum proton spectrum in Fig. 2.19 is based on the 1959 spectrum predicted by the solar-wind modulation theory of Durgaprasad et al.⁵⁶ The solar-minimum alpha-particle spectrum in Fig. 2.19 is taken from the review of McDonald and the solar-maximum alpha-particle spectrum in Fig. 2.19 is taken from the review of McDonald and the solar-maximum alpha-particle spectrum in Fig. 2.19 is taken from the review of McDonald and the experimental

Y

^{*}See Refs. 2, 8, 55, and the many references given therein.

^{55.} F. B. McDonald, "IQSY Observations of Low-Ene by Galactic and Solar Cosmic Rays," in Annals of the IQSY, Vol. 4, Ed. A. C. Strickland, M.I.T. Press, Cambridge (1969), p. 187.

^{56.} N. Durgaprasad, C. E. Fichtel, and D. E. Guss, "Solar Modulation of Cosmic Rays and Its Relationship to Proton and Helium Fluxes, Interstellar Travel, and Interstellar Secondary Production," J. Geophys. Res. 72, 2765 (1967).

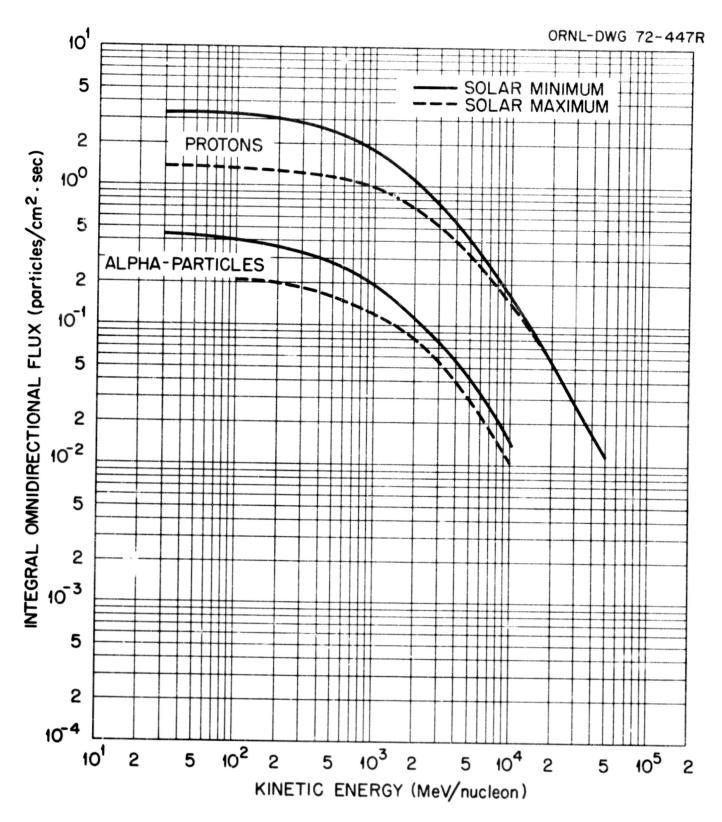


Fig. 2.19. Integral flux of galactic cosmic-ray protons and alpha particles.

data of McDonald, 57 Frier et al., 58 and Fan et al. 59 In Fig. 2.20 are shown the differential omnidirectional solar-minimum and solar-maximum proton fluxes per unit energy per nucleon and the solar-minimum alpha-particle flux per unit energy per nucleon, which, when integrated over energy per nucleon, gives the corresponding fluxes in Fig. 2.19.

The variation between the maximum and minimum in the galactic cosmicray fluxes of protons and alpha particles results from changes in solar activity. It has been observed over a great number of years that the average
intensity varies in a more or less regular way which generally follows the
approximate ll-year cycle of solar activity. When the maximum activity of
the solar cycle is reached (as measured, for example, by the sunspot number),
the cosmic-ray intensity reaches a minimum and then starts increasing until
the maximum is reached at the time of minimum solar activity. Galactic
cosmic-ray intensities are subject to other short-time variations (hours to
a few days), but, in general, these variations are small and are not important in shield design. For shielding purposes, the solar-minimum and
solar-maximum spectra may be taken as upper and lower limits, respectively,
on the particle fluxes that will be encountered in the space outside of the
magnetosphere.

The intensity and energy spectra of the heavy-particle components

(atomic weight > 4) of galactic cosmic rays are not as well established as

the intensity and energy spectra of the proton and alpha-particle components,

^{57.} F. B. McDonald, "Direct Determination of Primary Cosmic Ray Alpha Particle Energy Spectrum by New Method," Phys. Rev. 104, 1723 (1956).

^{58.} P. S. Frier, E. P. Ney, and C. J. Waddington, "Flux and Energy Spectrum of Cosmic-Ray α Particles During Solar Maximum," Phys. Rev. <u>114</u>, 365 (1959).

^{59.} C. Y. Fan, G. Glockler, and J. A. Simpson, "Cosmic Radiation Helium Spectrum Below 90 MeV Per Nucleon Measured on Imp I Satellite," J. Geophys. Res. 20, 3515 (1965).

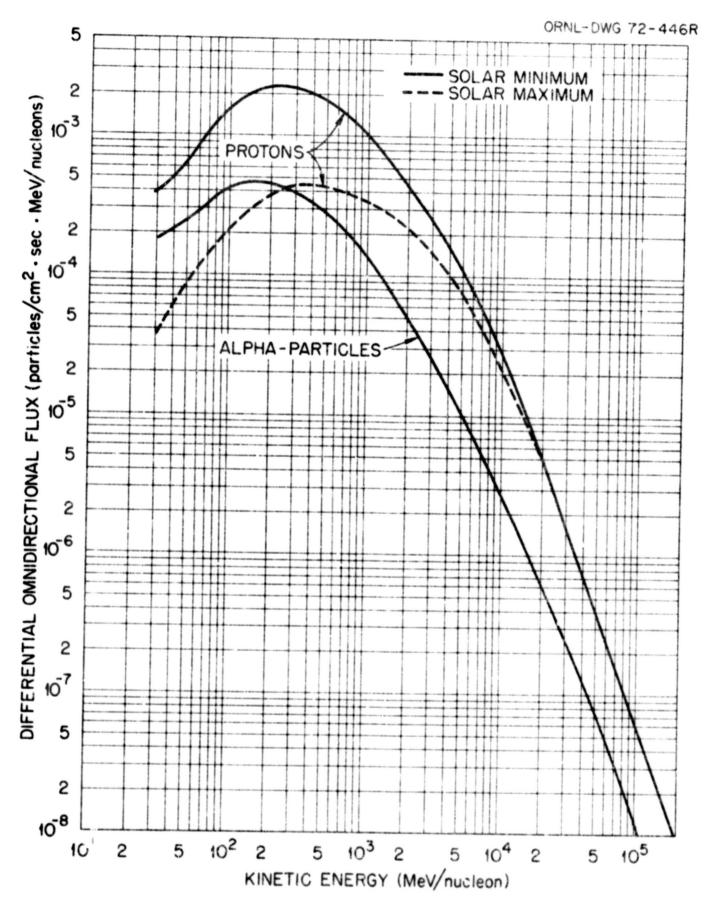


Fig. 2.20. Differential omnidirectional galactic proton flux at solar minimum and solar maximum and alpha-particle flux at solar minimum.

but considerable information is available. 8 In Table 2.5 the relative abundances of the various nuclides in galactic cosmic rays, based on the review article of Webber in Ref. 8, are given. The precise meaning of these abundances is not clear because the energy limits over which they were measured are not clear, but here it will be assumed that the abundances given in Table 2.5 correspond to the number of nuclei of a given type per cm² per sec above 30 MeV per nucleon divided by the number of alpha particles per ${\rm cm}^2$ per sec above 30 MeV per nucleon. The relative abundance of protons given in Table 2.5 corresponds to the solar-minimum proton and alpha-particle spectra given in Figs. 2.19 and 2.20; i.e., the relative abundance of protons given in Table 2.5 was obtained by dividing the number of protons per ${\rm cm}^2$ per sec above 30 MeV per nucleon from Fig. 2.19 by the number of alpha particles per cm² per sec above 30 MeV per nucleon from Fig. 2.19. The energy spectrum for elements with atomic weight > 4 in the galactic cosmic rays is usually assumed to have the same shape as that for galactic cosmic-ray alpha particles when all spectra are expressed in terms of energy per nucleon. This means that the differential omnidirectional flux per unit energy per nucleon for any heavy cosmic-ray nuclei may be obtained by multiplying the alpha-particle flux per unit energy per nucleon given in Fig. 2.20 by the appropriate relative abundance from Table 2.5. The spectra obtained by this procedure must be considered to be very approximate, but they represent the best estimates that are presently available.

Shielding calculations for incident galactic cosmic rays are somewhat different from those for solar cosmic rays and Van Allen belt protons because of the much higher energies involved. It will be shown later in this report that to a reasonable approximation the secondary particles produced

TABLE 2.5

Relative Abundance of Galactic Cosmic-Ray Nuclei
Outside of the Earth's Magnetic Field

Element	Relative Abundance (abundance of He taken to be unity)
H	7.27
Не	1.00
Li-B	2.34×10^{-2}
С	2.63×10^{-2}
N	1.20×10^{-2}
0	1.61×10^{-2}
F	2.34 × 10 ⁻³
Ne	4.77×10^{-3}
Na	2.09×10^{-3}
Mg	3.93×10^{-3}
A1	7.53×10^{-4}
Si	2.84×10^{-3}
P-Sc	1.84×10^{-3}
Ti-Ni	3.68 × 10 ⁻³

by nuclear reactions may be neglected or drastically approximated in shielding against solar cosmic-ray protons and Van Allen belt protons. In the case of galactic cosmic rays, because of the higher energies involved, this is not the case, and thus to carry out shielding calculations a large amount of differential particle-production cross-section data from high-energy nuclear collisions must be available.

Fortunately, the intensity of galactic cosmic rays is sufficiently small (of the order of a few particles cm⁻² sec⁻¹) that the dose an astronaut will receive from them (of the order of 10 rads year⁻¹ without shielding^{60,61} may be neglected unless long missions are considered.* For this reason, shielding against galactic cosmic rays has not been considered as extensively as shielding against solar-flare and Van Allen belt protons.

In Chapter 7 of this report are presented calculated results for the incident proton spectra, shown in Fig. 2.20, which take into account the secondary particles from nuclear reactions. Shielding calculations for incident galactic cosmic-ray alpha particles and heavy nuclei, which take into account the particles produced by nuclear reactions, cannot be carried out

^{*}The biological effects of high-energy, very heavy nuclei are not well understood, and it may be that this component of the galactic cosmic rays will pose a special hazard which is yet to be evaluated. 62

^{60.} J. R. Winckler, "Primary Cosmic Rays," Radiat. Res. 14, 521 (1956).

^{61.} E. S. Matusevich and S. G. Tsypin, "Radiation Shielding of a Man in Space," At. Energ. (USSR) 15, 499 (1963).

^{62. &}quot;Radiation Protection Guides and Constraints for Space-Mission and Vehicle-Design Studies Involving Nuclear Systems," Report of the Radiobiological Advisory Panel of the Committee on Space Medicine, Space Science Board, National Academy of Sciences, National Research Council, Washington, D. C., 1970.

at the present time because the required high-energy nuclear reaction cross-section data are not available. In Appendix 4 of this report, very approximate shielding results for incident galactic cosmic-ray alpha particles and heavy nuclei are presented.

Chapter 3

PARTICLE TRANSPORT AND DOSE CALCULATIONS

The transport of heavy charged particles, but not the nuclear-reaction products produced by such particles, through matter has been extensively investigated for many years and is a quite well understood phenomenon. 63,64 In this chapter the charged-particle transport equations applicable in space-shielding calculations are discussed. No attempt has been made to give a complete discussion of all aspects of charged-particle transport, but rather consideration has been restricted to those aspects of such transport that are significant in space shielding.

3.1 PRIMARY-PARTICLE TRANSPORT WITH ATTENUATION FROM NUCLEAR COLLISIONS

When a heavy charged particle, e.g., a proton or an alpha particle, passes through matter, it loses energy by the excitation and ionization of atomic electrons and undergoes nuclear collisions. The loss of energy by ionization and excitation occurs by a large number of discrete small steps and is most conveniently treated as a continuous process. In essentially all of the space-shielding calculations that have been done to date, it has been assumed that heavy charged particles undergo a continuous slowing down and travel in a straight line. This is an approximation since it is well known that heavy charged particles, in passing through matter, undergo both

^{63.} H. Bethe and J. Ashkin, "Passage of Radiation Through Matter," in Experimental Nuclear Physics, E. Segre, Ed., Part II, John Wiley & Sons, Inc., New York, 1963.

^{64.} B. Rossi, <u>High-Energy Particles</u>, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1952.

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angular deflection and range straggling, 63 , 65 , 66 but these effects are small, 67 and the use of the approximation greatly simplifies space-shielding computations.

When a heavy-particle-nucleus nonelastic collision occurs, the incident particle is absorbed and a variety of particles is emitted. When a heavy-particle-nucleus elastic collision occurs, the incident particle undergoes an energy loss and angular deflection, and the struck nucleus acquires kinetic energy. The energy losses and angular deflections of protons and alpha particles due to elastic collisions with heavy nuclei are sufficiently small that they may be neglected. In hydrogenous media, however, the effects of proton and alpha-particle collisions with hydrogen nuclei are not entirely negligible, and therefore these collisions are often not neglected.

It is convenient to distinguish between incident particles that have not undergone nuclear collision and the products of nuclear collision because, for many space-shielding purposes, the effects of the reaction products may be neglected and because, in general, the transport of the reaction products is more complicated than the transport of those incident particles that have not undergone nuclear collision. For the purposes of this work, a primary particle will be defined to be an incident particle that has undergone neither an elastic nor a nonelastic nuclear collision.

^{65.} M. J. Berger, "Monte Carlo Calculation of the Diffusion of Fast Charged Particles," in <u>Methods of Computational Physics</u>, Vol. I, Academic Press, New York, 1963, p. 135.

^{66.} R. M. Sternheimer, "Range Straggling of Charged Particles in Be, C, Al, Cu, Pb, and Air," Phys. Rev. 117, 485 (1960).

^{67.} R. G. Alsmiller, Jr., J. Barish, and W. W. Scott, "The Effects of Multiple Coulomb Scattering and Range Straggling in Shielding Against Solar-Flare Protons," Nucl. Sci. Eng. 35, 405 (1969).

With this definition and using the continuous slowing-down and straight-ahead approximations, it follows from conservation of particles that the equation for primary-particle flux in any direction in a homogeneous shield may be written

$$\frac{\partial}{\partial \mathbf{r'}} \Phi_{\mathbf{j}}^{\prime}(\mathbf{E}, \mathbf{r'}) + \sigma_{\mathbf{Sj}}^{\prime}(\mathbf{E}) \Phi_{\mathbf{j}}^{\prime}(\mathbf{E}, \mathbf{r'}) = \frac{\partial}{\partial \mathbf{E}} \left[\mathbf{S}_{\mathbf{Sj}}^{\prime}(\mathbf{E}) \Phi_{\mathbf{j}}^{\prime}(\mathbf{E}, \mathbf{r'}) \right], \quad \mathbf{j} = \mathbf{p}, \alpha$$
 (3.1)

$$\sigma_{Sj}' = \sum_{a} n_{Sa} \sigma_{aj} , \qquad (3.2)$$

where

 p,α = the subscripts which are used to denote protons and alpha particles, respectively;*

E = the particle kinetic energy;

- r' = the position coordinate measured along the direction of
 motion of the particles being considered;
- $\Phi_{j}^{\prime}(E,r^{\prime})$ = the flux of primary particles of type j per unit kinetic energy at position r';
 - n_{Sa} = the number density of target nuclei of type a in the shield denoted by subscript S (the sum over a in Eq. 3.2 is to be carried out over all nuclear species in the shield);
 - σ_{aj} = the total cross section for the collision of a particle of type j with a nucleus of type a (since elastic collisions with nuclei other than hydrogen will be neglected, σ_{aj} is for elements other than hydrogen taken to be the nonelastic cross section);

^{*}In all of the equations of this and subsequent sections, the subscript j may be put equal to either p or α , so an explicit indication of this will not be given.

 $S_{Sj}^{\prime}(E)$ = the energy loss per unit distance, i.e., the stopping power, of a particle of type j in the shielding material considered.

In space-shielding calculations it is convenient to use the variable $\rho r'$, where ρ is the density of the shield, rather than r'. Equation 3.1 when divided by ρ becomes

$$\frac{\partial}{\partial (\rho \mathbf{r'})} \Phi_{\mathbf{j}}^{\prime}(\mathbf{E}, \mathbf{r'}) + \frac{\sigma_{\mathbf{Sj}}^{\prime}(\mathbf{E})}{\rho} \Phi_{\mathbf{j}}^{\prime}(\mathbf{E}, \mathbf{r'}) = \frac{\partial}{\partial \mathbf{E}} \left[\frac{1}{\rho} S_{\mathbf{Sj}}^{\prime}(\mathbf{E}) \Phi_{\mathbf{j}}^{\prime}(\mathbf{E}, \mathbf{r'}) \right], \qquad (3.3)$$

and, with the definitions

$$r = \rho r'$$

$$\sigma_{Sj}(E) = \frac{1}{\rho} \sigma_{Sj}'(E)$$

$$S_{Sj}(E) = \frac{1}{\rho} S_{Sj}'(E)$$

$$\Phi_{j}(E,r) = \Phi_{j}'(E,r'),$$
(3.4)

becomes

$$\frac{\partial \Phi_{j}(E,r)}{\partial r} + \sigma_{Sj}(E) \Phi_{j}(E,r) = \frac{\partial}{\partial E} [S_{Sj}(E) \Phi_{j}(E,r)]. \qquad (3.5)$$

Equation 3.5 has the same form as Eq. 3.1 but the symbols have slightly different meanings. In particular, if r' is measured in cm, then r is measured in g cm⁻². In the remainder of this work, Eq. 3.5 will be used; i.e., it will be assumed that the transformation to the variable or' has been made.

Equation 3.5 may be solved to yield*

$$\Phi_{j}(E,r) = \Phi_{jo}(E_{j}) \frac{S_{Sj}(E_{j})}{S_{Sj}(E)} \exp \left[- \int_{E}^{E_{j}} \frac{\sigma_{Sj}(E')}{S_{Sj}(E')} dE' \right]$$
(3.6)

$$\int_{E}^{E_{j}} \frac{dE'}{S_{S_{j}}(E')} = r , \qquad (3.7)$$

where

jo (E) = the angular flux per unit energy of particles of type j
 which are incident on the shield.

^{*}A derivation of this equation is given in Appendix 1.

The function $\Phi_{jo}(E)$ may be any of the incident spectra discussed in Chapter 2. Since, however, $\Phi_{jo}(E)$ must be an angular flux, it is obtained by dividing the omnidirectional fluxes, $-\frac{dJ(>E)}{dE}$, of Chapter 2, which are assumed to be isotropic, by 4π . In the case of solar flares, the incident flux has been integrated over time so, properly speaking, Φ_{jo} and Φ_{jo} are fluences rather than fluxes.

The simplicity of Eqs. 3.6 and 3.7 is a direct consequence of the approximations that have been made. Because of the continuous slowing-down and straightahead approximations, the flux of particles per unit energy in a given direction depends only on the thickness r and the incident spectrum. Equation 3.7 expresses the fact that a particle of type j that enters the shield with energy E will have the energy E at depth r. In Eqs. 3.6 and 3.7 E must be greater than zero. If E is set equal to zero in Eq. 3.7, then r is the distance that a particle of type j with energy E will travel in the shield. The r value so determined is called the range of the particle with energy E in the shield. For a specific choice of shield thickness, r, Eq. 3.7, with E set equal to zero, determines the minimum incident-particle energy that can reach depth r; i.e., all incident particles of type j with energy < E jmin, defined by

$$\int_{0}^{E_{jmin}} \frac{dE'}{S_{Sj}(E')} = r , \qquad (3.8)$$

will come to rest before reaching depth r. In Eq. 3.6 the exponential factor describes the attenuation of the incident particles due to nuclear reactions. The ratio $\frac{S_{S_j}(E_j)}{S_{S_j}(E)}$ in Eq. 3.6 is a Jacobian which transforms from an energy range dE to an energy range dE_j. To understand this, note that from Eq. 3.7

$$\frac{\partial E_{j}}{\partial E} \bigg|_{r} = \frac{S_{Sj}(E_{j})}{S_{Sj}(E)}. \tag{3.9}$$

Equations 3.1-3.7 are written for a single homogeneous medium. The flux of particles that have passed through a succession of different homogeneous media may be obtained by successive utilization of Eqs. 3.6 and 3.7. To illustrate this, consider the case of a shield followed by tissue and let r_S be the thickness of the shield in the direction of the incident particles being considered. If $r < r_S$, then Eqs. 3.6 and 3.7 are valid and give the flux at a depth r in the shield. If $r > r_S$, then Eqs. 3.6 and 3.7 may be used, but the initial flux to be used in the equations is that which exists at the shield-tissue interface. Thus,

$$\Phi_{j}(E,r) = \Phi_{j}(E'_{j},r_{S}) \frac{S_{Tj}(E'_{j})}{S_{Tj}(E)} \exp \left[- \int_{E}^{E'_{j}} \frac{\sigma_{Tj}(E'')}{S_{Tj}(E'')} dE'' \right], \quad r > r_{S},$$
 (3.10)

$$\int_{E}^{E'_{j}} \frac{dE''}{S_{T_{j}}(E'')} = r - r_{S} , \qquad (3.11)$$

where

- $\Phi_{j}(E,r)$ = the angular flux per unit energy of particles of type j at the depth $r-r_{S}$ in the tissue;
- j(Ej,rs) = the angular flux per unit energy of particles of type j

 at the shield tissue interface;
 - $S_{T_{j}}(E)$ = the stopping power of tissue for particles of type j;
 - $\sigma_{Tj}(E)$ = the total macroscopic nuclear-reaction cross section for a particle of type j in the tissue.

If now $\phi_j(E',r_S)$ is taken from Eqs. 3.6 and 3.7,

$$\phi_{j}(E,r) = \phi_{j}(E,r_{S},r_{T}) = \phi_{jo}(E_{j}) \frac{S_{Sj}(E_{j})}{S_{Sj}(E_{j}')} \frac{S_{Tj}(E_{j}')}{S_{Tj}(E)}$$

$$\exp\left[-\int_{E_{j}^{\prime}}^{E_{j}} \frac{\sigma_{Sj}(E'')}{S_{Sj}(E'')} dE''\right] \exp\left[-\int_{E}^{E_{j}^{\prime}} \frac{\sigma_{Tj}(E'')}{S_{Tj}(E'')} dE''\right], \quad r > r_{S}, \quad (3.12)$$

$$\int_{E_{j}^{'}}^{E_{j}} \frac{dE''}{S_{Sj}(E'')} = r_{S} , \qquad (3.13)$$

$$\int_{E}^{E'_{j}} \frac{dE''}{S_{T_{j}}(E'')} = r - r_{S} = r_{T}, \qquad (3.14)$$

and thus $\phi_j(E,r)$ may be obtained provided the stopping powers and cross sections are known as functions of energy. The notation $\phi_j(E,r_S,r_T)$ will be used to indicate that ϕ_j depends on both r_S and r_T . The extension of Eq. 3.12 to the case of more than two successive homogeneous media is straightforward.

3.2 SECONDARY-PARTICLE TRANSPORT

In writing the equations of the previous section, nuclear reactions were treated as absorptions and no account was taken of the particles that are emitted from such reactions. A large variety of secondary particles (neutrons, protons, alpha particles and heavy nuclei, photons, and charged and neutral pions) is emitted, and a complete shielding analysis must include the effects of these particles. Because of the large variety of particles involved and because of the large amount of differential cross-section data required to describe the many nuclear reactions that may occur in the shield

^{68.} R. G. Alsmiller, Jr., "High-Energy Nucleon Transport and Space Vehicle Shielding," Nucl. Sci. Eng. 27, 158 (1967).

and in tissue, such a complete analysis is very complex. For shielding against Van Allen belt, solar-flare, and galactic cosmic-ray protons, computer codes capable of carrying out such an analysis, at least in simplified geometries, exist. 69-71 Fortunately, in shielding against Van Allen belt and solar-flare protons, the contribution of the secondary particles to the dose an astronaut will receive is not large and may be neglected or estimated very approximately. The contribution of the secondary particles to the dose in the case of incident galactic cosmic-ray protons is not small compared to the dose from primary protons, but the total dose is small and need be considered only for long missions. 60,61 In the subsequent sections of this report, a variety of calculated results which include contributions from secondary particles will be presented and compared with results obtained neglecting or approximating these contributions. Since, however, for the large majority of present-day space-shielding calculations a detailed knowledge of secondary-particle transport is not needed, an extensive discussion of this transport will not be given here. Such a discussion may be found in Ref. 68. The details associated with obtaining the secondaryparticle results given in the body of the report are given in Appendix 3.

^{69.} W. A. Coleman and T. W. Armstrong, "The Nucleon-Meson Transport Code NMTC," Oak Ridge National Laboratory Report ORNL-4606, 1970.

^{70.} K. C. Chandler and T. W. Armstrong, "Operating Instructions for the High-Energy Nucleon-Meson Transport Code HETC," Oak Ridge National Laboratory Report ORNL-4744, 1972.

^{71.} T. W. Armstrong, R. G. Alsmiller, Jr., K. C. Chandler, and B. L. Bishop, "Monte Carlo Calculations of High-Energy Nucleon-Meson Cascades and Comparison with Experiment," Oak Ridge National Laboratory Report ORNL-TM-3667, 1972; to be published in Nucl. Sci. Eng.

3.3 ABSORBED DOSE AND DOSE EQUIVALENT

To assess the effectiveness of a shield in protecting an astronaut, it is necessary to obtain a measure of the biological hazard associated with the radiation absorbed in the astronaut. The quantities usually used for this purpose are the absorbed dose and the dose equivalent. The absorbed dose is the energy deposited per gram of tissue at a specific point in the astronaut. The dose equivalent is obtained by weighting the energy deposited per gram of tissue by each particle at a specific point in the astronaut with a quality factor that is dependent on the stopping power of tissue for the particle and adding the weighted contribution of all particles.

Both the absorbed dose and the dose equivalent may be calculated from the primary-proton flux per unit energy. Consider a spacecraft with an astronaut inside and consider a point in the astronaut at which the dose (either the absorbed dose or dose equivalent) is desired. A ray drawn from this dose point passes through a thickness $r_T^{m{t}}$ of tissue and $r_S^{m{t}}$ of shield, and the angular flux per unit energy at the dose point from particles incident on the spacecraft along this ray may be calculated by the method described in Section 3.1 of this report. The thicknesses $\textbf{r}_{T}^{\:\raisebox{3.5pt}{\text{\circle*{1.5}}}}$ and $\textbf{r}_{S}^{\:\raisebox{3.5pt}{\text{\circle*{1.5}}}}$ may be parameterized by the polar angles of the ray with respect to an arbitrarily drawn coordinate system, and the omnidirectional flux per unit energy at the dose point may be obtained by adding the contribution from all rays, i.e., by integrating over the parametric polar angles. Finally, the absorbed dose, which is defined to be the energy deposited per gram of tissue, may be obtained by multiplying the omnidirectional flux per unit energy by the energy loss per unit distance in tissue and integrating over all energies. The equation for the absorbed dose is then

$$D_{j} = C \int_{0}^{2\pi} d\phi \int_{-1}^{1} d(\cos\theta) \int_{0}^{E''_{jmax}} dE \Phi_{j}[E, r'_{S}(\theta, \phi), r'_{T}(\theta, \phi)] S_{Tj}(E) , \qquad (3.15)$$

where

- D_j = the absorbed dose at the point being considered due to
 incident particles of type j;
- C = a constant which converts from energy deposition per unit volume to rad. [If energy is measured in MeV, then $C = (1.6 \times 10^{-8} \text{ rad})/(\text{MeV/g}).$]

 E''_{jmax} = the maximum energy of a particle of type j at the dose point; and $\Phi_{j}(E,r_{S},r_{T})$ is to be obtained from Eq. 3.12.

The dose equivalent D_{Qj} is obtained in much the same manner as the absorbed dose, but the energy deposited by each particle is weighted with a quality factor that is a function of the stopping power of tissue for the particle being considered; 72 that is,

$$D_{Qj} = C_{Q} \int_{0}^{2\pi} d\phi \int_{-1}^{1} d(\cos\theta) \int_{0}^{E''_{jmax}} dE$$

$$\Phi_{j}[E,r'_{S}(\theta,\phi), r'_{T}(\theta,\phi)] S_{Tj}(E) Q[S_{Tj}(E)], \qquad (3.16)$$

where

 C_Q = a constant which converts from weighted energy deposition per unit volume to rem. [If energy is measured in MeV, then $C_Q = (1.6 \times 10^{-8} \text{ rem})/(\text{MeV/g})$.]

It should be noted that in Eq. 3.16 the quality factor Q does not have a subscript j. 72

^{72. &}quot;Recommendations of the International Commission on Radiological Protection," ICRP Publication No. 9, Pergamon Press, New York, 1966.

To carry out the integrations in Eqs. 3.15 and 3.16 is problematic. This would be particularly true if these equations were written for a real spacecraft since the shield would not be homogeneous, and along a given ray a sequence of many different materials would be encountered by the incident radiation. In the case of a real spacecraft, not only would the numerical integrations be complicated but the information required about the spacecraft would be very extensive and, in general, not available. Approximation methods that may be used to obtain the fluxes and carry out the dose integrals in the case of a complex spacecraft are described later in this work.

For an isotropic incident flux per unit energy, the integrations in Eqs. 3.15 and 3.16 can be carried out in a straightforward manner if the geometry is sufficiently simple. Consider, for example, the geometry shown in Fig. 3.1; i.e., consider the case of a spherical shell shield with a sphere of tissue at the center and consider the dose at the center of the tissue. In this case, only those particles that are incident on the outside of the shield along a radius vector contribute to the dose, and all particles that contribute pass through the same thickness of shield material, vacuum, and tissue. Then, in Eqs. 3.15 and 3.16, the flux per unit energy Φ_{Sj} is independent of the angles θ, Φ , and the integration over these angles may be carried out to give

$$D_{j}(r_{S},r_{T}) = 4\pi C \int_{0}^{E_{jmax}^{"}} dE \Phi_{j}(E,r_{S},r_{T}) S_{Tj}(E)$$
 (3.17)

$$D_{Qj}(r_S, r_T) = 4\pi C_Q \int_0^{E''} dE \, \Phi_j(E, r_S, r_T) \, S_{Tj}(E) \, Q[S_{Tj}(E)],$$
 (3.18)

where E' is determined from the equations

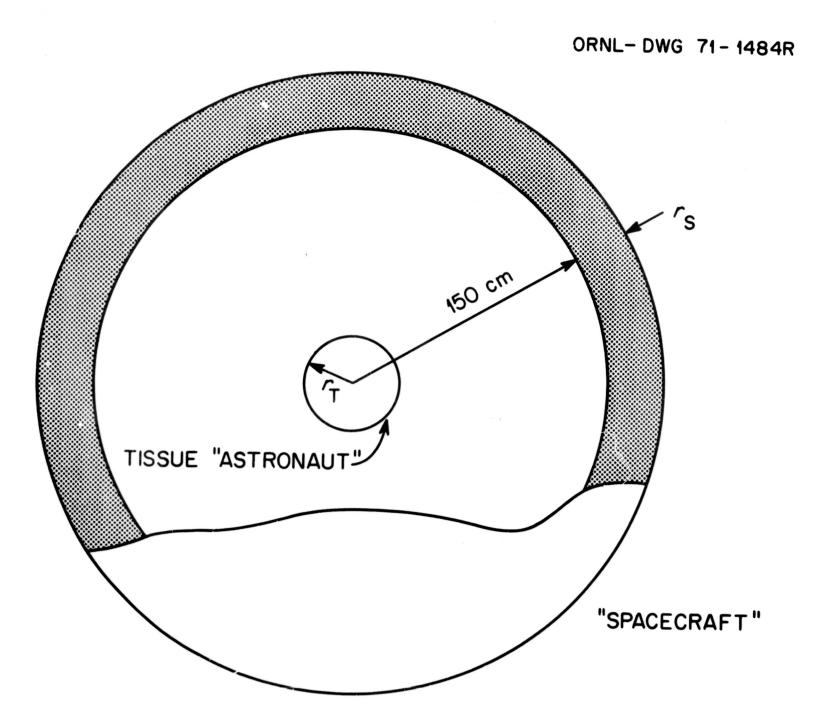


Fig. 3.1. A schematic diagram of the "spacecraft-astronaut" configuration.

$$\int_{E_{jmax}}^{E_{jmax}} \frac{dE'}{S_{Sj}(E')} = r_{S}$$
(3.19)

$$\int_{E''jmax}^{E'jmax} \frac{dE'}{S_{Tj}(E')} = r_{T} , \qquad (3.20)$$

with

 E_{jmax} = the maximum incident energy of a particle of type j.

It should be remembered that $\Phi_{\mathbf{j}}$ in Eqs. 3.17 and 3.18 is the angular flux per unit energy. For an isotropic flux, 4π $\Phi_{\mathbf{j}}$ is the omnidirectional flux per unit energy, so the equations could be written in terms of the omnidirectional flux per unit energy.

It must be emphasized that Eqs. 3.17 and 3.18 are valid only at the center of the tissue sphere. The dose as a function of position in the tissue sphere can be calculated only from the more general equations, i.e., from Eqs. 3.15 and 3.16.

Equations 3.17 and 3.18 express the absorbed dose and dose equivalent, respectively, at the center of the tissue sphere in terms of an integral over the particle flux per unit energy at the center of the sphere. These doses can also be expressed as integrals over the incident-particle flux per unit energy by transforming the integration variable from E to E_j. Equation 3.12 may be written

$$\Phi(E,r_{S},r_{T}) dE = \Phi_{jo}(E_{j}) X_{Sj}(E_{j},E_{j}') X_{Tj}(E_{j}',E) \frac{S_{Sj}(E_{j})}{S_{Sj}(E_{j}')} \frac{S_{Tj}(E_{j}')}{S_{Tj}(E)} dE$$
 (3.21)

$$X_{Sj}(E_{j},E_{j}') = \exp \left[- \int_{E_{j}'}^{E_{j}} \frac{\sigma_{Sj}(E'')}{S_{Sj}(E'')} dE'' \right]$$
 (3.22)

$$X_{Tj}(E'_{j},E) = \exp \left[- \int_{E}^{E'_{j}} \frac{\sigma_{Tj}(E'')}{S_{Tj}(E'')} dE'' \right]$$
 (3.23)

$$\int_{E_{j}^{*}}^{E_{j}} \frac{dE''}{S_{Sj}(E'')} = r_{S}$$
 (3.24)

$$\int_{E}^{E'_{j}} \frac{dE''}{S_{T_{j}}(E'')} = r_{T}. \qquad (3.25)$$

Equation 3.24 gives

$$E_{j} = E_{j}(E_{j}', r_{S})$$

$$dE_{j} = \frac{\partial E_{j}}{\partial E_{j}'} dE_{j}', dE_{j}', dE_{j}'$$

and, using Eq. 3.9,

$$dE_{j} = \frac{S_{Sj}(E_{j})}{S_{Sj}(E_{j})} dE_{j}' . \qquad (3.26)$$

In like manner, Eq. 3.25 gives

$$E = E(E'_{j}, r_{T})$$

$$dE = \frac{\partial E}{\partial E'_{j}} \Big|_{r_{T}} dE'_{j}$$

$$= \frac{S_{T_{j}}(E)}{S_{T_{j}}(E'_{j})} dE'_{j}, \qquad (3.27)$$

so, combining Eqs. 3.26 and 3.27,

$$dE_{j} = \frac{S_{Sj}(E_{j})}{S_{Sj}(E_{j}')} \frac{S_{Tj}(E_{j}')}{S_{Tj}(E)} dE , \qquad (3.28)$$

and Eq. 3.21 becomes

$$\Phi(E,r_{S},r_{T}) dE = X_{Sj}(E_{j},E_{j}') X_{Tj}(E_{j}',E) \Phi_{jo}(E_{j}) dE_{j}, \qquad (3.29)$$

where in X_{Sj} and X_{Tj} the energies E_j and E must be expressed in terms of E_j , r_S , and r_T with Eqs. 3.24 and 3.25.

Now specializing to the geometry of Fig. 3.1 and calculating the dose at the center of the tissue sphere, Eqs. 3.17 and 3.18 become

$$D_{j}(r_{S},r_{T}) = 4\pi C \int_{E_{jmin}}^{E_{jmax}} dE_{j} \Phi_{jo}(E_{j}) X_{Sj}(E_{j},E'_{j}) X_{Tj}(E'_{j},E) S_{Tj}(E)$$
 (3.30)

$$D_{Qj}(r_{S},r_{T}) = 4\pi C_{Q} \int_{E_{jmin}}^{E_{jmax}} dE_{j} \Phi_{jo}(E_{j}) X_{Sj}(E_{j},E_{j}')$$

$$X_{Tj}(E_{j}',E) S_{Tj}(E) Q[S_{Tj}(E)], \qquad (3.31)$$

where

 E_{jmax} = the maximum energy of an incident particle of type j,

 E_{jmin} = the minimum energy of an incident particle of type j

that can reach the center of the tissue sphere,

and again in Eqs. 3.30 and 3.31 the energies E_j' and E must be expressed in terms of E_j , r_S , and r_T with Eqs. 3.24 and 3.25. The energy E_{jmin} may be determined from the equations

$$\int_{E_{j}^{'}}^{E_{j}\min} \frac{dE'}{S_{Sj}(E')} = r_{S}$$
 (3.32)

$$\int_{0}^{E'_{j}} \frac{dE'}{S_{T_{j}}(E')} = r_{T} . \qquad (3.33)$$

Equations 3.30 and 3.31 are completely equivalent to Eqs. 3.17 and 3.18, and either set of equations may be used for numerical computations.

3.4 PRIMARY-PROTON TRANSPORT WITHOUT ATTENUATION FROM NUCLEAR COLLISIONS AS AN APPROXIMATION METHOD FOR INCLUDING SECONDARY PARTICLES

The nuclear reaction cross sections $\sigma_{\mbox{Si}}$ and $\sigma_{\mbox{Ti}}$ for the primary particle fluxes per unit energy appear in Eq. 3.12. The simplest approximation method for including the effects of secondary particles is to neglect these cross sections, i.e., to set them equal to zero, in calculating the primary-particle flux per unit energy. This may be considered as an approximate method for including secondary particles in that it is equivalent to the assumption that when a nuclear collision occurs a single particle of the same kind as the incident particle is emitted with the same energy and in the same direction as the incident particle. When one considers the large variety of particles, energies, and angles that can arise from a nuclear collision, it is clear that this is a gross oversimplification from the point of view of the physics involved, but this, of course, does not invalidate it from a numerical point of view. Also, the computation of the flux from Eq. 3.12 is simplified if the cross sections are set equal to zero, and for this reason the approximation is to be preferred. The validity of the approximation was considered some time ago by More and Tiffany. 73,74 In Chapter 6 its validity is reexamined in some detail by comparing calculated results obtained using the approximation with calculated results obtained including secondary-particle production and transport.

^{73.} K. A. More and O. L. Tiffany, "Comparison of Monte Carlo and Ionization Calculations for Spacecraft Shielding," Proc. Symposium on the Protection Against Radiation Hazards in Space, Gatlinburg, Tennessee, November 5-7, 1962, TID-7652, Book 2, p. 682.

^{74.} K. A. More and O. L. Tiffany, "Cosmic-Ray Shower Production in Manned Space Vehicles - Copper," Proc. Second Symposium on Protection Against Radiations in Space, Gatlinburg, Tennessee, October 12-14, 1964, NASA SP-71, 1964, p. 183.

For future reference, it is to be noted that in the approximation

$$\sigma_{Sj}^{(E)} = \sigma_{Tj}^{(E)} = 0$$
 (3.34)

Eq. 3.12, 3.13, and 3.14 become

$$\phi_{j}(E,r_{S},r_{T}) = \phi_{jo}(E_{j}) \frac{S_{Sj}(E_{j})}{S_{Sj}(E_{j}')} \frac{S_{Tj}(E_{j}')}{S_{Tj}(E)}$$
(3.35)

$$\int_{E_{j}^{*}}^{E_{j}} \frac{dE'}{S_{Sj}(E')} = r_{S}$$
 (3.36)

$$\int_{E}^{E_{j}^{i}} \frac{dE'}{S_{T_{j}}(E')} = x - r_{S} = r_{T}. \qquad (3.37)$$

For the absorbed dose and dose equivalent, respectively, Eqs. 3.17 and 3.18 do not change, but the alternate expressions for these quantities given by Eqs. 3.30 and 3.31 do simplify in that X_{Sj} and X_{Tj} become unity. Thus, Eqs. 3.30 and 3.31 become

$$D_{j}(r_{S},r_{T}) = 4\pi C \int_{E_{jmin}}^{E_{jmax}} dE_{j} *_{jo}(E_{j}) S_{Tj}(E)$$
 (3.38)

$$D_{Qj}(r_S, r_T) = 4\pi C_Q \int_{E_{jmin}}^{E_{jmax}} dE_j +_{jo}(E_j) S_{Tj}(E) Q(S_{Tj}(E)),$$
 (3.39)

where E must again be expressed in terms of E_j through Eqs. 3.36 and 3.37.

3.5 EQUIVALENT-THICKNESS APPROXIMATION

As pointed out previously, to carry out the integrations in Eqs. 3.15 and 3.16 for the case of an actual spacecraft is very problematic. In this section, an approximation method that may be used to simplify shielding calculations for very complex spacecraft is discussed.* The method is usually applied only when absorption of primary particles due to nuclear collisions is neglected, so only the transport equations with the nuclear cross sections set equal to zero will be used.

The basic equation of the equivalent-thickness approximation may be written

$$S_{Aj}^{(E)} = K_{ACj} S_{Cj}^{(E)}$$
, (3.40)

where

- S_{Aj}(E) the energy loss per unit distance of a particle of type j in an arbitrary material which is denoted by the subscript A;
 - *ACj = a quantity which is independent of E but whose value may depend on the material A, the standard material C, and the type of particle;
- Scj (E) the energy loss per unit distance of a particle of type j in some standard material which is denoted by the subscript C.

 Equation 3.40 is to hold for any material A, so it relates the stopping power of all materials to that of a single material. The validity of a relation such as that given by Eq. 3.40 is discussed later in this report. To

The space-shielding code of Liley and Hamilton, 75 which is discussed later in this report, utilizes a form of the equivalent-thickness approximation. The approximation described here differs from that used by Liley and Hamilton in that it does not require that the stopping powers have a specific an lytic form.

^{75.} B. Liley and S. C. Hamilton, "Modified Elemental Volume Dose Program (MEVDP)," North American Rockwell Corp. Report AFWL-TR-69-68, 1971.

explain how such a relation may be used to simplify shielding calculations, it will first be applied to the equations of Section 3.4 for the geometry shown in Fig. 3.1.

With the equations

$$S_{Sj}(E) = K_{SCj} S_{Cj}(E)$$
 (3.41)

$$S_{T_{j}}(E) = K_{TC_{j}} S_{C_{j}}(E)$$
, (3.42)

Eqs. 3.35, 3.36, and 3.37 become

$$\phi_{j}(E,r_{S},r_{T}) = \phi_{jo}(E_{j}) \frac{S_{Cj}(E_{j})}{S_{Cj}(E)}$$
 (3.43)

$$\int_{\mathbf{E}_{\mathbf{j}}^{\mathbf{j}}}^{\mathbf{E}_{\mathbf{j}}^{\mathbf{j}}} \frac{d\mathbf{E}^{\mathbf{i}}}{S_{\mathbf{C}\mathbf{j}}(\mathbf{E}^{\mathbf{i}})} = K_{\mathbf{S}\mathbf{C}\mathbf{j}} \mathbf{r}_{\mathbf{S}}$$
(3.44)

$$\int_{E}^{E_{j}^{*}} \frac{dE'}{S_{C_{j}}(E')} = K_{TC_{j}} r_{T}. \qquad (3.45)$$

Equations 3.44 and 3.45 may be added to give

$$\int_{E}^{E_{j}} \frac{dE'}{S_{C_{j}}(E')} = K_{SC_{j}} r_{S} + K_{TC_{j}} r_{T}, \qquad (3.46)$$

and if now an equivalent thickness of material C, rC, is defined by

$$r_{c} = K_{SCj} r_{s} + K_{TCj} r_{T}$$
, (3.47)

Eq. 3.46 becomes

$$\int_{E}^{E_{j}} \frac{dE'}{S_{Cj}(E')} = r_{C}. \qquad (3.48)$$

Equations 3.43 and 3.48 no longer contain any reference to any material other than the standard one. The dose equations, 3.17 and 3.18, may be written

$$D_{j}(r_{C}) = 4\pi C K_{CTj} \int_{0}^{E'j_{max}} dE \Phi_{j}(E,r_{C}) S_{Cj}(E)$$
 (3.49)

$$D_{Qj}(r_C) = 4\pi C_Q K_{CTj} \int_{C}^{E''_{jmax}} dE \Phi_j(E,r_C) S_{Cj}(E) Q[K_{CTj} S_{Cj}(E)],$$
 (3.50)

where, of course, r_C still depends on r_S and r_T through Eq. 3.47. The important point is that D_j and D_{Qj} can be plotted as a function of r_C without reference to r_S and r_T , and then the doses can be obtained from the plot for any shield material and thickness and any tissue thickness by determining r_C from Eq. 3.47.

For the simple geometry shown in Fig. 3.1, the equivalent-thickness approximation is useful in reducing the computational effort required for shielding calculations, but in the case of complex geometries it is very powerful since the flux calculation need be carried out only as a function of the variable $\mathbf{r}_{\mathbf{C}}$ rather than as a function of the individual thicknesses of the various materials that the incident particles traverse in passing through the shield to the dose point. It should be noted that in the equivalent-thickness approximation, the information required about the shield is slightly reduced from that which would be required to carry out the calculations exactly in that only the total thickness of a given type of material enters into the determination of $\mathbf{r}_{\mathbf{C}}$; that is, the sequence of materials which the radiation passes through does not enter into the determination of $\mathbf{r}_{\mathbf{C}}$. For example, Eq. 3.47 would be unchanged if the radiation had passed through a thickness $\mathbf{r}_{\mathbf{T}}$ of tissue and then through a thickness $\mathbf{r}_{\mathbf{C}}$ of shield.

3.6 ANALYTIC STOPPING-POWER APPROXIMATION

In this section another approximation method that may be used to simplify shielding calculations for very complex spacecraft is discussed. 76-78 The method described here is the basis of the shielding code of Hill et al., 78 which is considered later in this report. This method, like the equivalent-thickness approximation, is usually applied only when absorption of primary particles due to nuclear collisions is neglected, so only the transport equations with the nuclear cross sections set equal to zero will be considered.*

The basis of the method is the assumption that the stopping power of any material may be approximated by the expression**

$$S_{Aj}(E) = \frac{E}{a_{Aj}h_j}[E^{-h_j} + 2b_{Aj}],$$
 (3.51)

where a_{Aj} and b_{Aj} are constants that depend on both the material and the type of particle and h_j is a constant that depends on the type of particle but is independent of the type of material. The validity of expressions such as that given by Eq. 3.51 is discussed later in this report. In this section, only the manner in which analytic expressions such as that given in Eq. 3.51 can be used to simplify shielding calculations will be considered.

^{*}A discussion of the manner in which nuclear cross sections may be included is given in Ref. 77.

^{**}This expression was introduced by Burrell in Ref. 77. A somewhat simpler expression had previously been used in similar calculations by Madey. 76

TIn principle, the method described here may also be applied if h, is dependent on the material. Since, however, the code of Hill et al., 78 which makes extensive use of the method, requires that h, be independent of material, this assumption will be made here.

^{76.} Richard Madey, "A Useful Formula for Calculating Space Proton Dose Rates," Trans. Am. Nucl. Soc. 60 (1), 194 (1963).

^{77.} M. O. Burrell, "The Calculation of Proton Penetrations and Dose Rates," George C. Marshall Space Flight Center Report NASA TM X-53063, 1964.

^{78.} C. W. Hill, W. B. Ritchie, and K. M. Simpson, "Dose Calculations in Space Vehicles," Lockheed-Georgia Company Report ER-7777, Vol. II, 1965.

The method will be explained by applying it to the equations of Section 3.4 for the geometry shown in Fig. 3.1. The essential point of stopping powers of the form of Eqs. 3.51 is that Eqs. 3.24 and 3.25 may be integrated to give

$$r_{s} = \frac{a_{sj}}{2b_{sj}} \ln(1 + 2b_{sj} E^{h_{j}}) \Big|_{E'_{j}}^{E_{j}}$$
 (3.52)

$$r_{T} = \frac{a_{Tj}}{2b_{Tj}} \ln(1 + 2b_{Tj} E^{h_{j}}) \Big|_{E}^{E'_{j}},$$
 (3.53)

and these equations may be solved to give

$$E_{j}^{h_{j}} = A_{Sj} + B_{Sj} A_{Tj} + B_{Sj} B_{Tj} E^{h_{j}}$$
 (3.54)

$$A_{Sj} = \frac{B_{Sj} - 1}{2b_{Sj}}$$
 (3.55)

$$B_{Sj} = \exp\left[\frac{2b_{Sj} r_{S}}{a_{Sj}}\right]$$
 (3.56)

$$A_{Tj} = \frac{B_{Tj}^{-1}}{2b_{Tj}}$$
 (3.57)

$$B_{Tj} = \exp\left[\frac{2b_{Tj} r_{T}}{a_{Tj}}\right] . \qquad (3.58)$$

Furthermore, differentiation of Eq. 3.54 gives

$$\frac{dE_{j}}{dE} = \frac{B_{Sj} B_{Tj} E^{h_{j}-1}}{\left[A_{Sj} + B_{Sj} A_{Tj} + B_{Sj} B_{Tj} E^{h_{j}}\right]^{(h_{j}-1)/h_{j}}},$$
(3.59)

and then using Eq. 3.28 the flux, Eq. 3.35, may be expressed as

$$\Phi_{j}(E,r_{S},r_{T}) = \frac{\Phi_{jo}(E_{j}) B_{Sj} B_{Tj} E^{h_{j}-1}}{\left[A_{Sj} + B_{Sj} A_{Tj} + B_{Sj} B_{Tj} E^{h_{j}}\right]^{(h_{j}-1)/h_{j}}}$$
(3.60)

where E_j in Φ_{jo} is to be obtained from Eq. 3.54. Thus, by means of the analytic stopping-power expressions the flux may be expressed analytically provided the incident flux is known analytically. The dose calculations, expressed by Eqs. 3.17 and 3.18, must still in general be carried out numerically. In the special case of an incident spectrum that is describable as a power law in energy, the absorbed-dose integral can be expressed in terms of incomplete beta functions. 77,78

The advantage of the method for geometries that are much more complex than that shown in Fig. 3.1 is that Eq. 3.54 may be generalized, and the flux per unit energy at a point inside the spacecraft may be obtained in analytic form even when the radiation incident along a given direction passes through a very complex sequence of thicknesses of different materials. Since the integrations in Eqs. 3.17 and 3.18 must still be carried out numerically, the calculations required to obtain the absorbed dose and dose equivalent at a point inside a complex shield are rather formidable even when the approximation method discussed in this section is employed. The fact that the absorbed-dose integral may be expressed in terms of incomplete beta functions in the case when the incident spectrum is represented as a power law in energy is extensively exploited in Ref. 78.

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Chapter 4

PHYSICAL DATA

In order to carry out the numerical evaluation of the particle fluxes and doses discussed in Chapter 3, it is necessary to have numerical values for the various physical quantities, i.e., stopping powers, cross sections, etc., which appear in the equations. The ultimate validity of the calculated results is dependent not only on the accuracy of the approximations made in deriving the equations but is also dependent on the accuracy of the data used in the calculations. In this chapter, the data available for use in space-shielding calculations are discussed and the data used in the later calculations in this report are described.

4.1 ENERGY LOSS PER UNIT DISTANCE AND RANGE OF PROTONS IN MATTER

The energy loss per unit distance of heavy charged particles in matter has been the subject of much experimental and theoretical research for many years and is a well-understood phenomenon. There are three recent extensive tabulations of stopping-power and range data for protons suitable for use in space-shielding calculations. In the report of Janni, the proton stopping power is tabulated for energies between 0.1 and 1000 MeV for 46 elements and 26 materials. In the report of Hill et al., the proton stopping power is given in the energy range 1 to 105 MeV for 55 materials,

^{79.} J. F. Janni, "Calculations of Energy Loss, Range, Pathlength, Straggling, Multiple Scattering, and the Probability of Inelastic Nuclear Collisions for 0.1 to 1000-MeV Protons," AFWL-TR-65-150, 1966.

^{80.} C. W. Hill, W. B. Ritchie, and K. M. Simpson, "Data Compilation and Evaluation of Space Shielding Problems, Range, and Stopping Power Data," Lockheed-Georgia Company Report ER-7777, Vol. I, 1965.

^{81.} W. H. Barkas and M. J. Berger, "Tables of Energy Loss and Range of Heavy Charged Particles," NASA SP-3013, 1964.

and in the work of Barkas and Berger, ⁸¹ the stopping power is given in the energy range 1 to 5000 MeV for a large variety of elements and materials. The physical parameters that enter into the calculations, represented by these tabulations, are slightly different, but the basic methods of calculation are similar. In Table 4.1 results from the three tabulations are compared for several materials, and the three calculations are in reasonable agreement. There are significant differences at the lower energies and the polyethylene results of Hill et al. are slightly lower than those of the other authors. In general, the differences shown in Table 4.1 would not have any appreciable effect on shielding calculations.

The proton stopping power is shown in Fig. 4.1 as a function of proton kinetic energy for copper, aluminum, polyethylene, and tissue. The data are taken from Ref. 79 below 1000 MeV and from Ref. 81 above 1000 MeV. In general, it is to be expected that the larger the stopping power the more effective the shield, and thus Fig. 4.1 indicates that on a g-cm⁻² basis polyethylene is a more effective shield than either aluminum or copper. The calculated doses presented later in this report show this to be the case. The stopping-power curves for all materials have the same general shape. This is of some importance since it is the basis of the equivalent-thickness approximation. It should also be noted that the stopping powers of all materials become very large at the lower energies. This will be very significant later when the shape of a proton spectrum as it penetrates a shield is considered.

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TABLE 4.1
Proton Stopping Power as a Function of Energy

	Stopping Power $\left(\frac{\text{MeV}}{\text{g/cm}^2}\right)$								
Proton Energy (MeV)	Polyethylene			Aluminum			Copper		
	Janni ⁷⁹	Hill et al.80	Barkas & Berger ⁸¹	Janni ⁷⁹	Hill et al. 80	Barkas & Berger ⁸¹	Janni ⁷⁹	Hill et al. 80	Barkas & Berger ⁸¹
0.5	484.36	457.24		251.99	255.92		167.45	177.41	
1.0	294.19	284.49		174.02	173.72		121.60	126.16	
2.0	176.95	172.11	182.47	110.82	110.30	112.40	80.408	82.165	83.224
10.0	49.744	48.782	49.555	33.965	33.912	33.796	27.123	27.375	27.315
50.0	13.375	13.169	13.356	9.6250	9.6281	9.6226	8.1076	8.1375	8.1474
100.0	7.8026	7.6918	7.7938	5.6952	5.6960	5.6963	4.8636	4.8824	4.8839
200.0	4.7946	4.7312	4.7899	3.5388	3.5379	3.5402	3.0530	3.0611	3.0636
400.0	3.2262	3.1886	3.2257	2.4041	2.4023	2.4064	2.0921	2.0939	2.0973
600.0	2.7118	2.6862	2.7152	2.0311	2.0310	2.0295	1.7763	1.7767	1.7809
800.0	2.4694	2.4484	2.4649	1.8562	1.8562	1.8562	1.6306	1.6270	1.6340
1000.0	2.3361	2.3160	2.3260	1.7607	1.7617	1.7611	1.5528	1.5460	1.5487
2000.0		2.1094	2.1131		1.6325	1.6258		1.4345	1.4394
5000.0		2.1159	2.1248		1.6807	1.6668		1.4781	1.4882

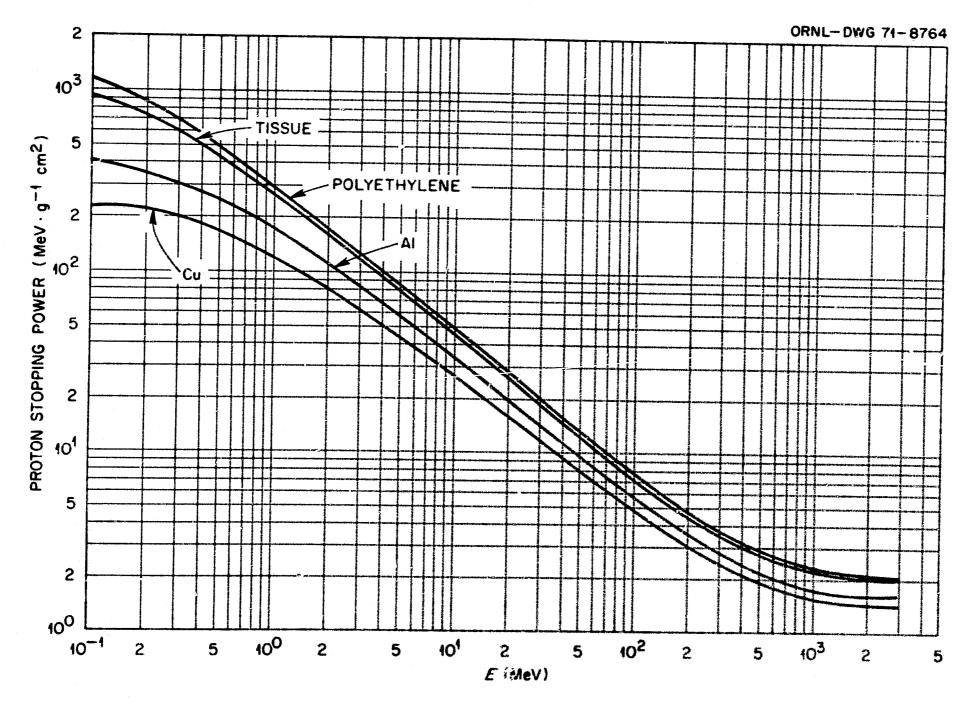


Fig. 4.1. Proton stopping power vs energy in various materials.

A quantity which is very useful in discussing charged-particle shielding and which is very closely related to the stopping power is the range of a proton in matter. The range of a particle of a given kinetic energy in a specific material is defined to be the distance the particle will travel before losing all of its energy. In the continuous slowing-down approximation, the range of a proton with kinetic energy E may be written as

$$R_{Ap}^{(E)} = \int_{0}^{E} \frac{dE'}{S_{Ap}^{(E')}}$$
, (4.1)

where

R_{Ap}(E) = the range of a proton with kinetic energy E in a material denoted by the subscript A.

References 79, 80, and 81 give tabulations of the proton range over the same energy intervals and for the same materials for which the stopping powers are given. In none of the tabulations is the stopping power at the very low energies given, and therefore, in principle, the integral in Eq. 4.1 over the entire energy range cannot be evaluated. To overcome this difficulty, Eq. 4.1 is rewritten in the form

$$R_{Ap}(E) = R_{Ap}(E_L) + \int_{E_L}^{E} \frac{dE'}{S_{Ap}(E')}$$
, (4.2)

where $R_{Ap}(E_L)$ is the range of a proton with some very low energy E_L and the quantity $R_{Ap}(E_L)$ is determined empirically (see, for example, Ref. 79).

The range of protons in copper, aluminum, polyethylene, and tissue is shown in Fig. 4.2 as a function of proton kinetic energy. The data below 1000 MeV are taken from the work of Janni⁷⁹ and the data above 1000 MeV are taken from the work of Barkas and Berger.⁸¹ The significant point to be noted

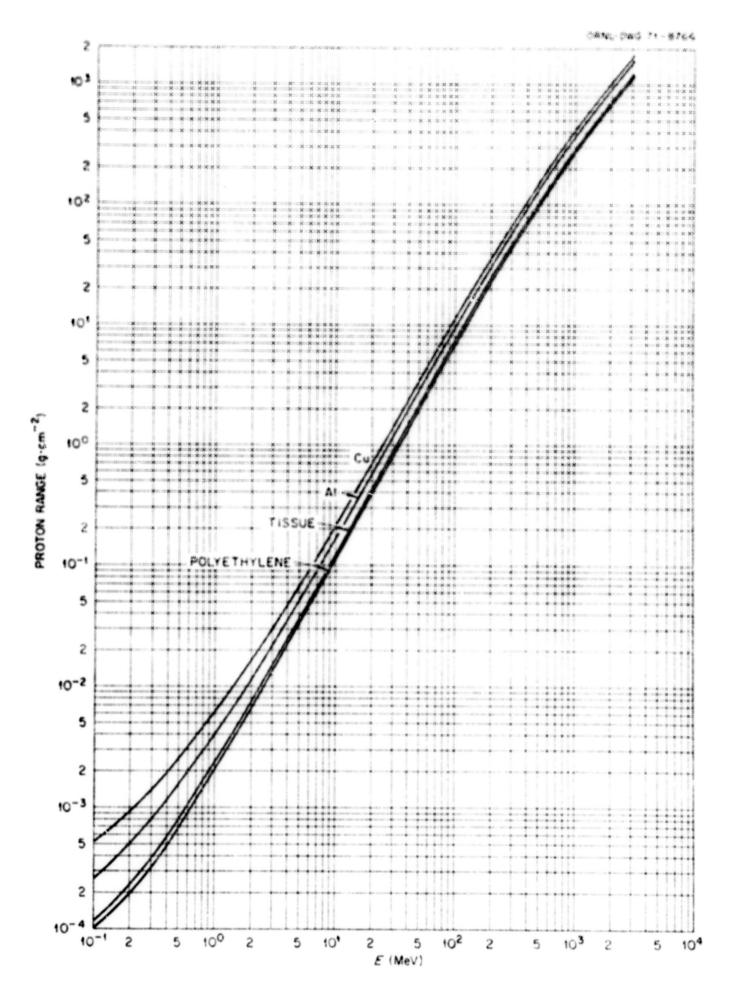


Fig. 4.2. Proton range vs energy in various materials.

is that the range decreases rapidly as the proton energy decreases. If a shield of a given thickness in g cm⁻² is considered, one can determine immediately from the range-vs-energy curves the lowest energy incident particle that can penetrate the shield.

4.2 ENERGY LOSS PER UNIT DISTANCE AND RANGE OF ALPHA PARTICLES IN MATTER

The energy loss per unit distance and range may be calculated for alpha particles in much the same manner as for protons. 63 Hill et al. 80 carried out the computations and tabulated the stopping powers and ranges of alpha particles in the energy range 2 to 10^5 MeV for 55 materials.

The stopping power of matter for alpha particles may also be obtained to a good approximation directly from proton stopping-power data for alpha-particle energies above a few MeV.* The expression for the stopping power of a particle of type j in a specific material may be written⁶³

$$S_{Aj}(E) = z_j^2 f_A(v_j)$$
, (4.3)

where

 z_{i} = the charge of a particle of type j,

 v_j = the velocity of a particle of type j,

and the function $f_A(v_j)$ is independent of the charge and mass of the particle of type j. Therefore, since $z_p = 1$,

$$S_{A\alpha}(E) = z_{\alpha}^2 S_{Ap} \left(\frac{M_p}{M_{\alpha}} E \right) ,$$
 (4.4)

where

^{*}The stopping powers for heavy nuclei (atomic weight > 4), such as those that occur in galactic cosmic rays, may also be obtained by the methods described here.

- Mp = the rest energy of the proton,
- M_{α} = the rest energy of the alpha particle.

At alpha-particle kinetic energies above a few MeV, the alpha particles may be assumed to be completely ionized so $z_{\alpha}=2$ and Eq. 4.4 may be used. At energies below a few MeV, the average charge of an alpha particle as it slows down is < 2; i.e., an alpha particle at these lower energies continually picks up and loses electrons, and a correction for this continual change in charge must be made.

One method of obtaining stopping-power data for alpha particles in this lower energy range is to assume that the shape of the stopping-power curve as a function of energy is independent of material and to scale the measured data for some standard element to agree with the results given by Eq. 4.4 at some energy sufficiently high that Eq. 4.4 may be assumed to be valid.* The measured alpha-particle stopping powers for several materials given in the article by Northcliffe⁸² somewhat justifies the assumption that the shape of the stopping-power curve as a function of energy at low energies does not depend strongly on material. To obtain low-energy stopping-power data for alpha particles for use in the calculations that are reported later in this report, the measured alpha-particle stopping-power curve in aluminum, as given by Northcliffe, 82 will be used and for all materials will be renormalized to agree with the results of Eq. 4.4 at 8 MeV.

^{*}This is much the same assumption that is used in the equivalent-thickness approximation (see Eq. 3.40), but it is being used here only over a very narrow energy range.

^{82.} L. C. Northcliffe, "Passage of Heavy Ions Through Matter," Appendix B in "Studies in Penetration of Charged Particles in Matter," Nuclear Science Series Report No. 39, National Academy of Sciences, National Research Council Publication 1133.

The energy loss per unit distance of alpha particles in copper, aluminum, polyethylene, and tissue is shown in Fig. 4.3 as a function of energy. The solid curves show the results obtained by the method just discussed and the plotted points are from the compilation of Hill $et\ al.^{80}$ The two different calculations are in good agreement at most energies, but there are slight differences at 2 MeV.

The alpha-particle stopping-power curves have the same general shape as do the proton stopping-power curves. It should be noted that at the lower energies (< 0.5 MeV) the alpha-particle stopping power decreases with decreasing energy. A similar decrease in the proton stopping power occurs but at energies of < 0.1 MeV, so it is not shown in Fig. 4.1.

The range of alpha particles may be calculated from the stopping power in the same manner as for protons; that is,

$$R_{A\alpha}(E) = \int_{0}^{E} \frac{dE'}{S_{A\alpha}(E')}$$
 (4.5)

$$= R_{A\alpha}(E_L) + \int_{E_L}^{E} \frac{dE'}{S_{A\alpha}(E')} , \qquad (4.6)$$

where

 $R_{A\alpha}(E)$ = the range of an alpha particle with kinetic energy E in a material denoted by the subscript A,

and E_L is some low energy below which the range must be determined empirically. Alpha-particle ranges in copper, aluminum, polyethylene, and in tissue from the compilation of Hill $et\ al.^{80}$ are shown in Fig. 4.4 as a function of energy. The significant point to note is that the alpha-particle range becomes very small at low alpha-particle energies.

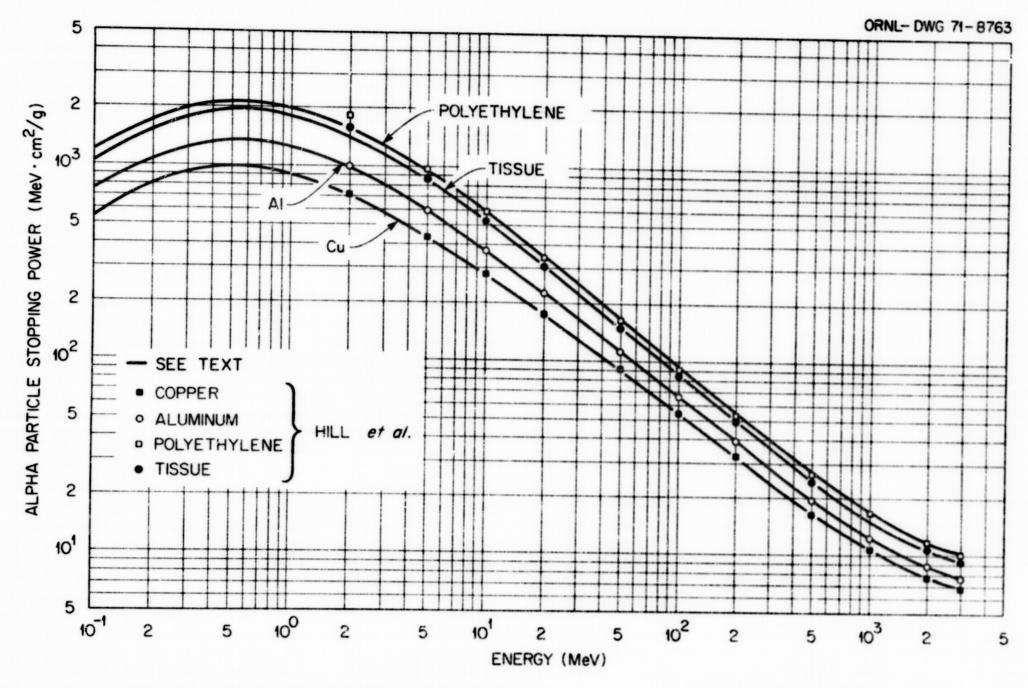


Fig. 4.3. Alpha-particle stopping power vs energy in various materials.

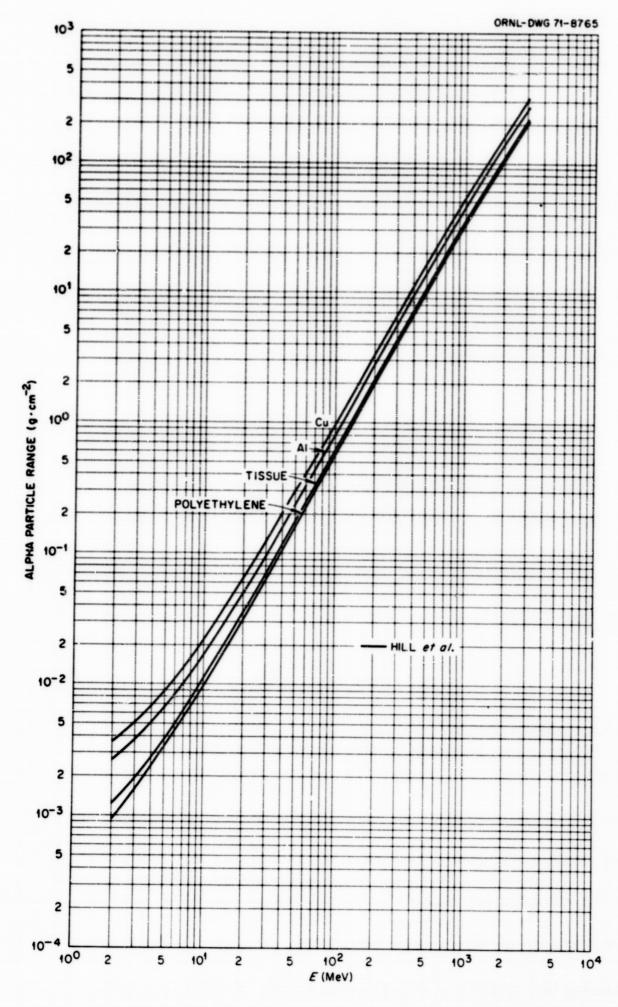


Fig. 4.4. Alpha-particle range vs energy in various materials.

If E_L in Eq. 4.6 is taken to be sufficiently large that Eq. 4.4 is valid, then Eqs. 4.2, 4.4, and 4.6 may be combined to give

$$R_{A\alpha}(E) - R_{A\alpha}(E_L) = \frac{1}{z_{\alpha}^2} \frac{M_{\alpha}}{M_{p}} \left[R_{Ap} \left(\frac{P}{M_{\alpha}} E \right) - R_{Ap} \left(\frac{P}{M_{\alpha}} E_L \right) \right]. \tag{4.7}$$

Equation 4.7 relates the alpha-particle and proton ranges. The relation is complicated by the presence of $R_{A\alpha}(E_L)$ and $R_{Ap}\left(\frac{M}{M}_{\alpha}E_L\right)$, but these quantities are not large for small values of E_L , so over a large energy range, i.e., $E >> E_L$, the relation

$$R_{A\alpha}(E) = \frac{1}{z_{\alpha}^{2}} \frac{M_{\alpha}}{M_{p}} R_{Ap} \left(\frac{M_{p}}{M_{\alpha}} E \right)$$
 (4.8)

may he used.

4.3 VALUES OF KACj FOR USE IN THE EQUIVALENT-THICKNESS APPROXIMATION

The basic assumption of the equivalent-thickness approximation is that given in Eq. 3.40; i.e.,

$$K_{ACj} = \frac{S_{Aj}(E)}{S_{Cj}(E)}. \qquad (4.9)$$

For the approximation to be usable, K_{ACj} must be independent of energy for all materials of interest and for some specific choice of the standard material denoted by the subscript C. The extent to which Eq. 4.9 may be satisfied, as well as appropriate values of K_{ACj} , is considered in this section.

It is clear that Eq. 4.9 is satisfied exactly with K_{ACj} equal to unity if the materials A and C are the same, so for application to a specific complex shield the standard material should be chosen to be the material that is most prevalent in the shield. In most complex shields, however, there are many materials present, so, in general, Eq. 4.9 must be used for many

materials with one specific choice of the standard material. With this in mind, aluminum will be used as the standard material throughout the remainder of this report.

The ratios of the proton stopping power in copper, polyethylene, and tissue to the proton stopping power in aluminum is shown in Fig. 4.5 as a function of energy. The data used in obtaining the ratios shown in the figure are the data given in Fig. 4.1. To satisfy exactly Eq. 4.9, the curves in Fig. 4.5 would have to be constant in energy, and this is clearly not the case. On the other hand, the major variation occurs below 10 MeV, and because of the large low-energy stopping power (see Fig. 4.1), this is not an important energy region for space-shielding purposes. Furthermore, because of the small number of high-energy protons in both solar-flare and Van Allen belt spectra (see Chapter 2), the high-energy region (≥ 500 MeV) is not of overwhelming importance in calculating the dose. In the intermediateenergy region that is of importance, the curves in Fig. 4.5 are not varying rapidly, and each may reasonably be approximated by a constant. The exact value to be used to obtain the best results is not clear and will depend to some extent on the shield thickness. The calculated results, which are presented later in this report (see Section 6.4), indicate that a reasonable choice of $K_{A,Al,p}$ is the ratio of the stopping powers at 50 MeV; i.e.,

$$K_{A,A\ell,p} = \frac{\left[S_{Ap}(E)\right]}{S_{A\ell p}(E)}_{E = 50 \text{ MeV}}$$
 (4.10)

It should be noted that the value of the energy at which the ratio is evaluated to define $K_{A,A\ell,p}$ may be taken to be a function of A, if this is found desirable.

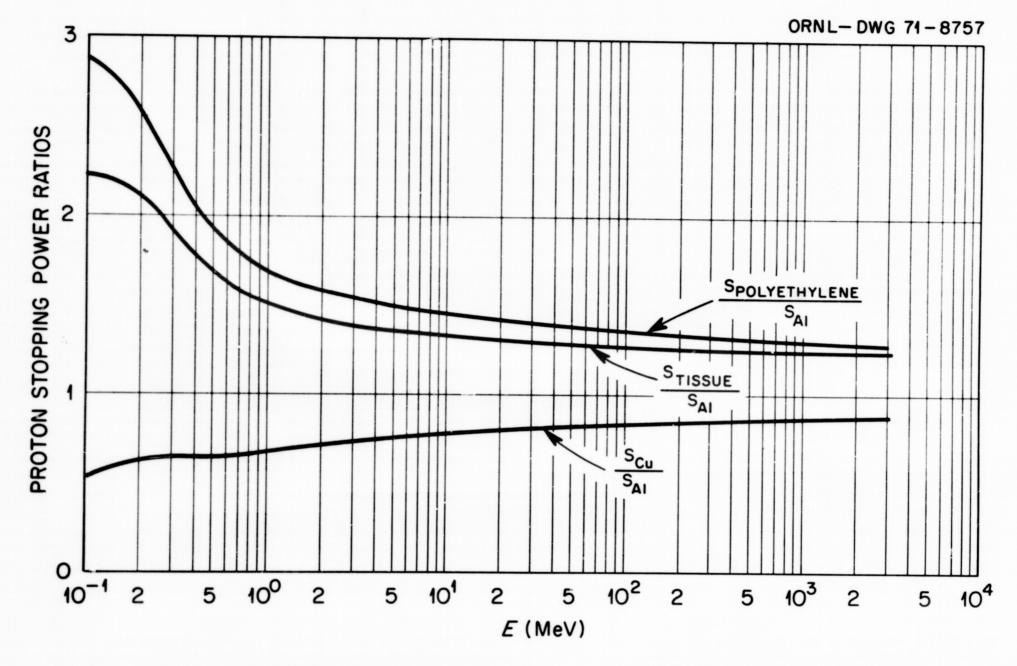


Fig. 4.5. Ratics of proton stopping power in various materials to the proton stopping power in aluminum vs energy.

The ratios of the alpha-particle stopping power in copper, polyethylene, and tissue to the alpha-particle stopping power in aluminum are shown in Fig. 4.6 as a function of energy. The data used in obtaining the ratios are the data shown by the solid curves in Fig. 4.3. Below 8 MeV, the ratios shown in the figure are constant in energy because of the approximate manner in which the data in this energy region were obtained. Above 8 MeV, the ratios are not constant, so Eq. 4.9 cannot be satisfied exactly for alpha particles. With alpha particles, as with protons, the very low and very high energy regions are of less importance in shielding calculations than is the intermediate-energy region, and therefore the approximate constant value of $K_{A_{\alpha}A\ell_{\bullet}\alpha}$ should be chosen to correspond to the stopping-power ratio in the intermediate-energy region. The exact value of $K_{\mbox{AC}\alpha}$, which will give the best results, will depend to some extent on shield thickness, but the calculated results that are presented later in this report (see Section 6.4) indicate that a reasonable choice of $K_{A,A\ell,\alpha}$ is the ratio of the stopping powers at 150 MeV; i.e.,

$$K_{A,A\ell,\alpha} = \frac{\left[S_{A\alpha}(E)\right]}{S_{A\ell\alpha}(E)}_{E = 150 \text{ MeV}}$$
 (4.11)

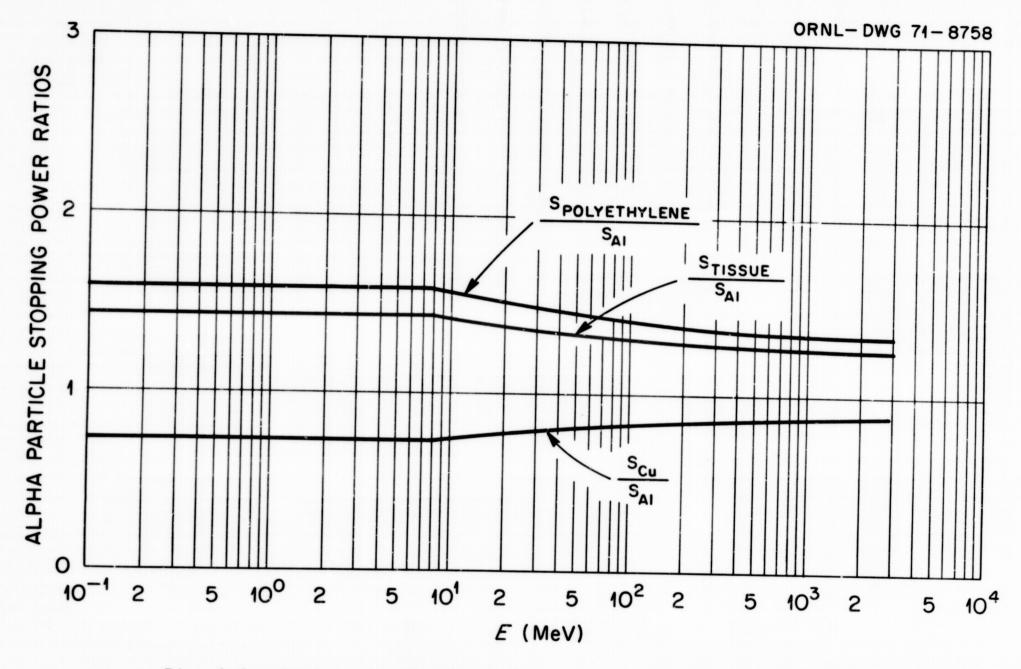


Fig. 4.6. Ratios of alpha-particle stopping power in various materials to the alpha-particle stopping power in aluminum vs energy.

4.4 ANALYTIC REPRESENTATION OF THE ENERGY LOSS PER UNIT DISTANCE OF PROTONS AND ALPHA PARTICLES IN MATTER

To apply the approximation method described in Section 3.6, it is necessary to represent the stopping powers of both protons and alpha particles in all materials of interest in the form

$$S_{Aj}(E) = \frac{E}{a_{Aj} b_{j}} [E^{-b_{j}} + 2b_{Aj}].$$
 (4.12)

With this form of the stopping power, the range may be written

$$R_{Aj}(E) = \frac{a_{Aj}}{2b_{Aj}} \ln(1 + 2b_{Aj} E^{h_{j}})$$
 (4.13)

if it is assumed that Eq. 4.12 is valid even at zero energy.

Hill et al. 80 have given sets of parameters for use in Eqs. 4.12 and 4.13 which represent their calculated stopping-power and range data over the energy range 10 to 1200 MeV. The sets of parameters for protons and alpha particles, respectively, for polyethylene, tissue, aluminum, and copper are shown in Tables 4.2 and 4.3. The maximum error given in the tables is the maximum error between the range value given by Eq. 4.13 and the tabulated range for energies between 10 and 1200 MeV. For each material several values of h_j have been considered, and, as indicated in the tables, the maximum error may be reduced if the appropriate value of h_j with the corresponding a_{Aj} and b_{Aj} are used for each material. To apply the method described in Section 3.6 to a complex shield containing many materials, it is necessary to choose a single value of h_j for all materials, and therefore it is necessary to use an h_j value that is nonoptimum for many of the materials.*

^{*}It is not necessary that the value of h, which occurs in the tissue stopping power in the dose integrals be the same as the value of h, used in the flux calculation.

TABLE 4.2

Parameters in Analytic Expression for Proton Stopping Power and Range in Various Materials

h	a	ь	Maximum % Error				
Polyethylene							
1.700	2.5629399×10^{-3}	9.6373122×10^{-8}	15.15				
1.725	2.3544716×10^{-3}	6.3069271×10^{-7}	11.36				
1.750	2.1833397×10^{-3}	1.5483591×10^{-6}	7.51				
1.775	1.9948323×10^{-3}	1.8089785×10^{-6}	4.05				
1.800	1.8093624×10^{-3}	2.1137309×10^{-6}	2.66				
1.825	1.6283789×10^{-3}	2.2156770×10^{-6}	4.86				
	Tissue						
1.700	2.7609269×10^{-3}	2.3786870×10^{-7}	14.38				
1.725	2.5363768×10^{-3}	7.8500710×10^{-7}	10.60				
1.750	2.3566435×10^{-3}	1.6768516×10^{-6}	6.57				
1.775	2.1544199×10^{-3}	2.0318594×10^{-6}	3.19				
1.800	1.9328651×10^{-3}	2.1622699×10^{-6}	2.79				
1.825	1.7666101×10^{-3}	2.5021080×10^{-6}	5.69				
Aluminum							
1.700	3.7050121×10^{-3}	7.8273580×10^{-7}	9.67				
1.725	3.3797255×10^{-3}	1.2831189×10^{-6}	6.27				
1.750	3.0971024×10^{-3}	2.0380825×10^{-6}	2.94				
1.775	2.7938117×10^{-3}	2.3455097×10^{-6}	2.36				
1.800	2.5521315×10^{-3}	2.7379606×10^{-6}	5.30				
1.825	2.3212658×10^{-3}	2.9244198×10^{-6}	8.39				
	Copper						
1.700	4.5399383×10^{-3}	1.5089631×10^{-6}	5.47				
1.725	4.1317101×10^{-3}	2.2296185×10^{-6}	2.59				
1.750	3.7512870×10^{-3}	2.6490541×10^{-6}	2.37				
1.775	3.4475860×10^{-3}	3.1833481×10^{-6}	5.38				
1.800	3.1503032×10^{-3}	3.4521199×10^{-6}	8.92				
1.825	2.8947234×10^{-3}	4.0209618×10^{-6}	12.06				

TABLE 4.3

Parameters in Analytic Expression for Alpha-Particle
Stopping Power and Range in Various Materials

h	a	ъ	Maximum % Error				
Polyethylene							
1.700	2.8626810×10^{-4}	1.3814511×10^{-8}	39.19				
1.725	2.4161725×10^{-4}	$9.0784292 \times 10^{-10}$	24.02				
1.750	2.0096030×10^{-4}	1.2502988×10^{-8}	12.34				
1.775	1.6996862×10^{-4}	1.1338430×10^{-8}	3.79				
1.800	1.5594513×10^{-4}	3.4233760×10^{-7}	4.28				
1.825	1.4398543×10^{-4}	7.4053385×10^{-7}	6.79				
	Tissue	1					
1.700	3.0455545×10^{-4}	6.9402984×10^{-9}	34.14				
1.725	2.5648746×10^{-4}	3.2738317×10^{-8}	20.77				
1.750	2.1542266×10^{-4}	6.5164801×10^{-9}	9.56				
1.775	1.8668739×10^{-4}	4.9534441×10^{-8}	3.68				
1.800	1.7284493×10^{-4}	6.2641855×10^{-7}	5.96				
1.825	1.5744799×10^{-4}	9.9299856×10^{-7}	8.92				
	Aluminu	m					
1.700	3.8442287×10^{-4}	1.9668971×10^{-8}	19.21				
1.725	3.1865129×10^{-4}	2.0284722×10^{-8}	7.81				
1.750	2.8722918×10^{-4}	2.8692487×10^{-7}	7.66				
1.775	2.6730275×10^{-4}	1.2048697×10^{-6}	10.45				
1.800	2.4074630×10^{-4}	1.3529143×10^{-6}	13.14				
1.825	2.2340503×10^{-4}	1.8300810×10^{-6}	17.21				
	Copper						
1.700	4.3893883×10^{-4}	3.8383463×10^{-7}	7.44				
1.725	4.0957925×10^{-4}	1.0648550×10^{-6}	9.93				
1.750	3.7481452×10^{-4}	1.6589254×10^{-6}	12.29				
1.775	3.4233624×10^{-4}	1.9068543×10^{-6}	15.51				
1.800	3.0521998×10^{-4}	2.0804788×10^{-6}	18.95				
1.825	2.8167787×10^{-4}	2.4912431×10^{-6}	21.72				

With this in mind, a single value of h_j for all materials will be used in the subsequent calculations. From Table 4.2 a reasonable value of h_p for the four materials shown would seem to be 1.775 since this is optimum for aluminum and near optimum for the other materials. In all subsequent calculations, $h_p = 1.775$ will be used. From Table 4.3 a reasonable value of h_α for the four materials shown would seem to be 1.775 since this value is optimum for polyethylene and tissue and near optimum for aluminum. It should be noted, however, that this value is far from optimum for copper. In subsequent calculations, $h_\alpha = 1.775$ will be used.

The proton and alpha-particle stopping powers, respectively, in copper, aluminum, polyethylene, and tissue are shown in Figs. 4.7 and 4.8 as a function of energy. The solid curves are the same as those shown in Figs. 4.1 and 4.3, the plotted points were obtained from Eq. 4.12 with $h_p = h_\alpha = 1.775$, and the corresponding a's and b's were obtained from Tables 4.2 and 4.3. In both figures, the values from Eq. 4.12 represent the curves rather well in the energy region of 10 to 1200 MeV that was used in obtaining the parameters. Outside of this energy range, however, the plotted points show significant deviations from the solid curves. It should be noted that in Fig. 4.8 the plotted points for aluminum and copper deviate from the solid curves even in the energy range of 10 to 1200 MeV. because the parameters used, i.e., h_{α} = 1.775, are not the best choices for aluminum and copper as indicated by the error column in Table 4.3. In subsequent sections of this report, the errors in the shielding calculations that result from using the analytic stopping-power data shown in Figs. 4.7 These errors are found to be small in the case of and 4.8 are evaluated. protons but excessive in the case of alpha particles.

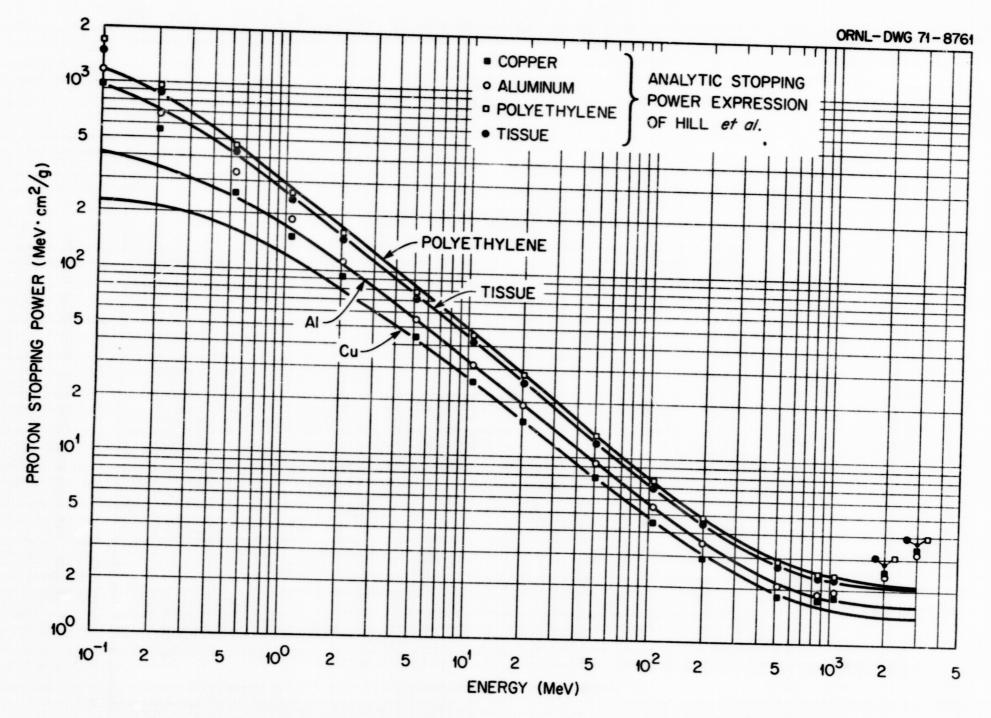


Fig. 4.7. Proton stopping power vs energy in various materials.

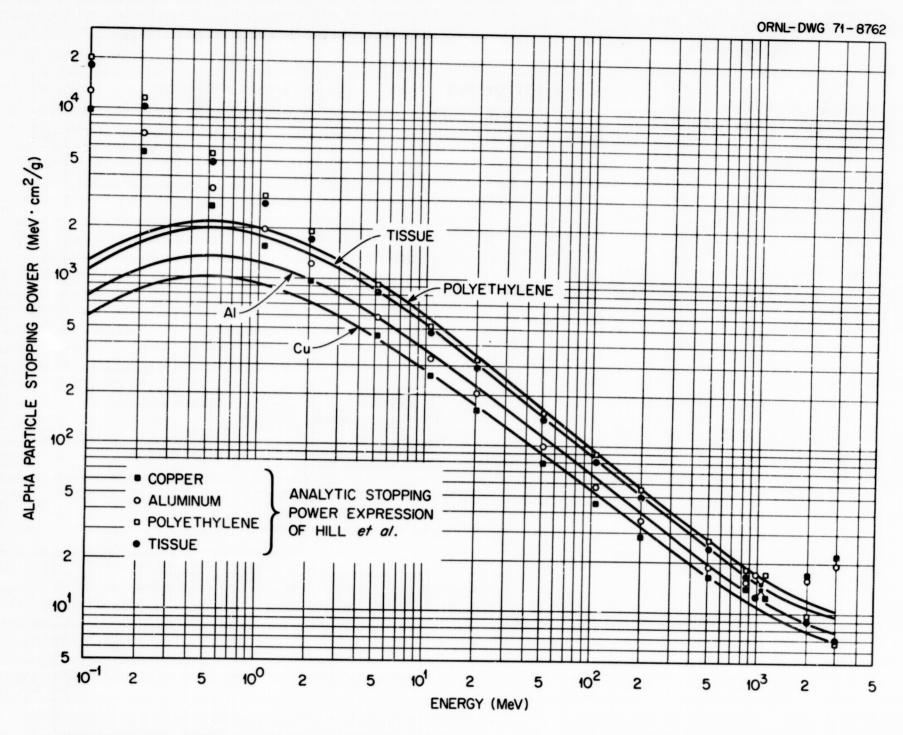


Fig. 4.8. Alpha-particle stopping power vs energy in various materials.

An alternate procedure to using the alpha-particle analytic stopping-power parameters of Hill $et\ al.^{80}$ is to obtain alpha-particle parameters from the proton parameter of Hill $et\ al.^{80}$ by means of Eq. 4.4. If the stopping-power expressions, Eq. 4.12, for protons and alpha particles are substituted into Eq. 4.4, one obtains the equation

$$\frac{1}{a_{A\alpha}h_{\alpha}} \left[E^{-h_{\alpha}} + 2b_{A\alpha} \right] = \frac{z_{\alpha}^{2} \left(\frac{M_{p}}{M_{\alpha}} \right)^{1-h_{p}}}{a_{Ap}h_{p}} \left[E^{-h_{p}} + 2\left(\frac{M_{\alpha}}{M_{p}} \right)^{p} b_{Ap} \right]$$
(4.14)

which may be satisfied for all values of E if \mathbf{h}_{A} , \mathbf{a}_{A} , and \mathbf{b}_{A} are defined by the equations

$$h_{\alpha} = h_{p} \tag{4.15}$$

$$a_{A\alpha} = \frac{1}{z_{\alpha}^{2}} \left(\frac{M_{\alpha}}{M_{p}} \right)^{1-h_{p}} a_{Ap}$$
 (4.16)

$$b_{A\alpha} = \left(\frac{M_{\alpha}}{M_{p}}\right)^{-h_{p}} b_{Ap} \qquad (4.17)$$

Equations 4.15 to 4.17 determine the alpha-particle parameters in terms of the proton parameters for any given material. The parameters obtained from Eqs. 4.15 to 4.17 are not at all the same as those given by Hill $et\ al.^{80}$ for alpha particles. The alpha-particle stopping power for copper, aluminum, polyethylene, and tissue is shown as a function of energy in Fig. 4.9. The solid curves are the same as those in Figs. 4.3 and 4.8, and the plotted points were obtained from Eq. 4.12 with the parameters obtained from Eqs. 4.15 to 4.17 and the proton parameters corresponding to $h_p = 1.775$. In Fig. 4.9

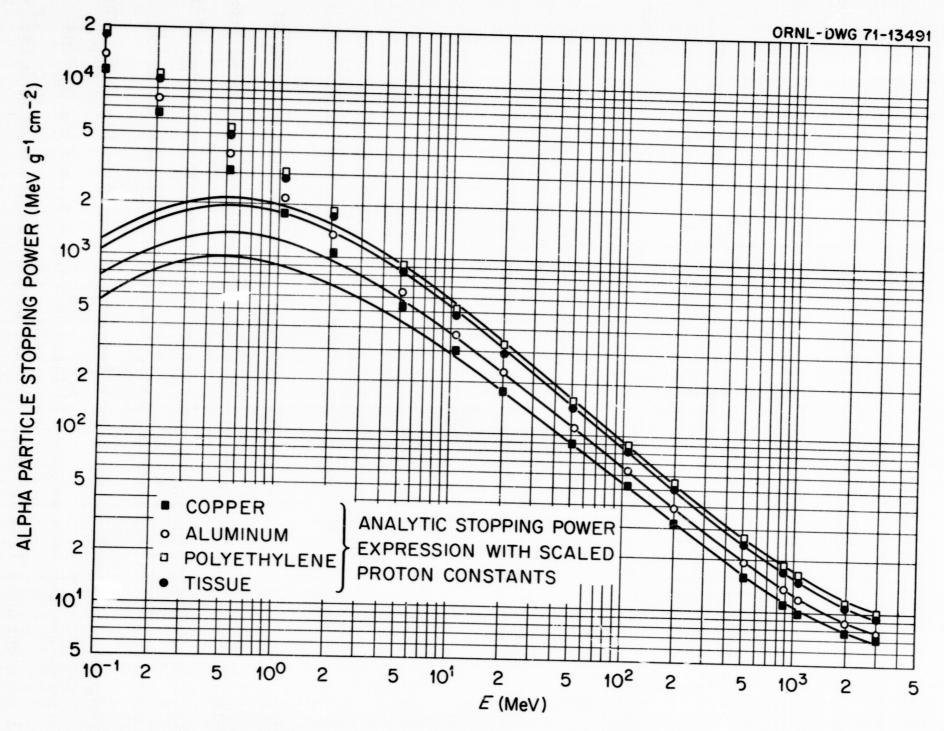


Fig. 4.9. Alpha-particle stopping power vs energy in various materials.

the plotted points are in good agreement with the solid curves at all energies above ~ 10 MeV. In particular, it should be noted that the agreement between the plotted points and the solid curves at energies > 1 GeV is much better than that shown in Fig. 4.8. In subsequent sections of this report, it is shown that in shielding calculations the value of the alphaparticle stopping power at energies > 1 GeV is of considerable importance and that therefore the alphaparticle stopping-power parameters given by Eqs. 4.15 to 4.17 lead to much more reliable results than those given in Table 4.3 from Ref. 80.

4.5 PROTON-NUCLEUS COLLISION CROSS SECTIONS

The proton-nucleus cross sections that occur in the equations of Chapter 3 were defined to be the proton-nucleus nonelastic cross sections for nuclei and the proton-proton total cross section in the case of hydrogen; i.e., elastic collisions with nuclei other than hydrogen were neglected, but elastic proton collisions with hydrogen were assumed to remove primary protons. Of course when secondary particles are considered, both of the protons from a proton-proton collision are considered as secondary particles.

The total cross section for proton-proton collisions as a function of energy is well established experimentally. The available experimental data have recently been reviewed by Barashenkov, 83 and the values used here are taken from this review.

^{83.} V. S. Barashenkov, "Interaction Cross Sections of Elementary Particles," translated from Russian by Y. Oren, Department of Physics, Tel Aviv University, Israel Program for Scientific Translation, Jerusalem, 1968.

In the energy range 25 to 3000 MeV, the nonelastic cross sections for protons incident on several elements have been calculated by Bertini.84,85* The calculated cross sections are in reasonable agreement with experimental data^{86,87} and are therefore suitable for use in shielding calculations. Calculated data are available for many of the elements commonly needed in space-shielding calculations. Furthermore, the cross-section values do not vary rapidly with material, and values for elements other than those contained in the Bertini calculations can readily be obtained by interpolation.^{88,89}

^{*}All of the data described in Refs. 84 and 85 are available on request from the Radiation Shielding Information Center of the Oak Ridge National Laboratory.

^{84.} H. W. Bertini, "Results from Low-Energy Intranuclear-Cascade Calculation," Nucl. Phys. 87, 138 (1968).

^{85.} H. W. Bertini and M. P. Guthrie, "Results from Medium-Energy Intranuclear-Cascade Calculations," Nucl. Phys. <u>A169</u>, 670 (1971).

^{86.} H. W. Bertini, "Low-Energy Intranuclear Cascade Calculations," Phys. Rev. 131, 1801 (1963); with erratum Phys. Rev. 138, AB2 (1965).

^{87.} H. W. Bertini, "Intranuclear-Cascade Calculation of the Secondary Nucleon Spectra from Nucleon-Nucleus Interactions in the Energy Range 340 to 2900 MeV and Comparisons with Experiment," Phys. Rev. 188, 1711 (1969).

^{88.} R. G. Alsmiller, Jr., M. Leimdorfer, and J. Barish, "Analytic Representation of Nonelastic Cross Sections and Particle-Emission Spectra from Nucleon-Nucleus Collisions in the Energy Range 25 to 400 MeV," Oak Ridge National Laboratory Report ORNL-4046, 1967.

^{89.} R. G. Alsmiller, Jr. and J. Barish, "NCDATA - Nuclear Collision Data for Nucleon-Nucleus Collisions in the Energy Range 25 to 400 MeV," Oak Ridge National Laboratory Report ORNL-4220, 1968.

In Fig. 4.10 the macroscopic total nuclear-collision cross sections for copper, aluminum, polyethylene, and tissue are plotted over the energy range 25 to 3000 MeV. The composition of tissue, shown in Table 4.4, was taken to be that used in several previous calculations 90-92 and is slightly different from that used by Janni. 79 The cross sections are not rapidly varying as a function of energy. The increase in the cross section in the vicinity of 300 to 400 MeV is due to the fact that pion production becomes energetically possible in this energy region. The cross sections are not zero below 25 MeV, but for shielding purposes they may be neglected at the lower energies because the proton stopping power is sufficiently large at these lower energies that the protons will, with high probability, come to rest without undergoing a nuclear collision. A more rigorous way of making this statement is that at energies of < 25 MeV the proton range is very small compared to the mean free path for proton-nucleus collisions, i.e., compared to the reciprocal of the macroscopic cross section.

^{90.} C. D. Zerby and W. E. Kinney, "Calculated Tissue Current-to-Dose Conversion Factors for Nucleons Below 400 MeV," Nucl. Instr. Meth. 36, 125 (1965).

^{91.} D. C. Irving, R. G. Alsmiller, Jr., and H. S. Moran, "Tissue Current-to-Dose Conversion Factors for Neutrons with Energies from 0.5 to 60 MeV," Nucl. Instr. Meth. <u>51</u>, 129 (1967).

^{92.} R. G. Alsmiller, Jr., T. W. Armstrong, and W. A. Coleman, "The Absorbed Dose and Dose Equivalent from Neutrons in the Energy Range 60 to 3000 MeV and Protons in the Energy Range 400 to 3000 MeV," Nucl. Sci. Eng. 42, 367 (1970).

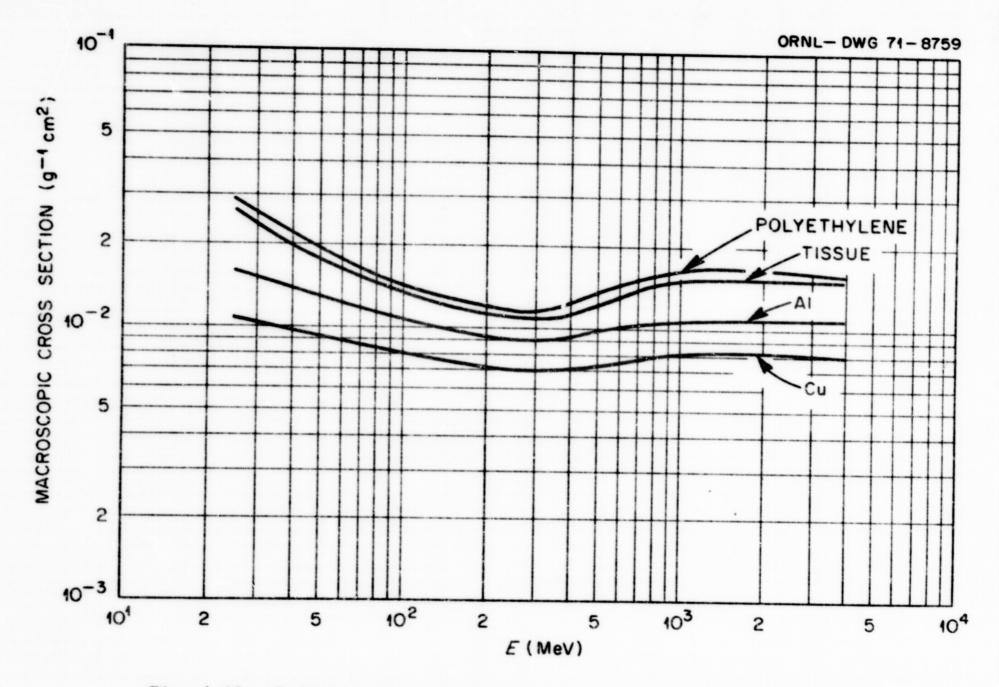


Fig. 4.10. Primary proton macroscopic nuclear-collision cross section vs energy in various materials.

TABLE 4.4
Composition of Tissue

Element	Number Density of Nuclei (No. cm ⁻³)		
Н	6.265×10^{22}		
C	9.398×10^{21}		
N	1.342×10^{21}		
0	2.551 × 10 ²²		

4.6 ALPHA-PARTICLE-NUCLEUS COLLISION CROSS SECTIONS

The alpha-particle-nucleus-collision cross sections that occur in the equations of Chapter 3 were defined in the same manner as the proton-nucleus cross sections; i.e., for alpha-particle collisions with nuclei other than hydrogen the collision cross section was defined to be the nonelastic cross section, and for alpha-particle collisions with hydrogen the collision cross section was defined to include both the elastic and nonelastic cross sections.

The total alpha-particle-proton-collision cross section has recently been calculated as a function of energy by Barashenkov and Eliseev. 93 These calculated results are in reasonable agreement with the experimental data and are therefore used here.

The alpha-particle-nucleus nonelastic cross sections for elements other than hydrogen are not available either experimentally or theoretically, and therefore only a relatively crude estimate of these cross sections can be made. Here it will be assumed that the nonelastic cross section for an element other than hydrogen can be approximated by the geometric expression*

$$\sigma_{A\alpha} = \pi r_0^2 (A^{1/3} + A_\alpha^{1/3})^2$$
, (4.18)

where

A, A_{α} = the atomic weight of the nucleus and alpha particle, respectively, and

$$r_o = 1.3 \times 10^{-13}$$
 cm.

^{*}See the review article by Webber in Ref. 8.

^{93.} V. S. Barashenkov and S. M. Eliseev, "Interaction Cross Sections of Nucleons with Helium," Joint Institute of Nuclear Research, Dubna, Report JINR-P2-4333, 1969.

The macroscopic collision cross section for alpha particles in several materials is shown in Fig. 4.11 in the energy range 25 to 3000 MeV. The composition of tissue is that used in Refs. 90-92 and shown in Table 4.4. The energy variation of the cross section in the case of polyethylene and tissue is due to the presence of hydrogen since, for elements other than hydrogen, the cross section is constant by assumption. The cross sections are not zero below 25 MeV, but, as in the case of protons, they may be neglected below this energy because the range of alpha particles of 25 MeV and less is small compared to the mean free path for alpha-particle-nucleus collisions; i.e., alpha particles with energies of 25 MeV and less will, with a very high probability, come to rest without undergoing a nuclear collision.

4.7 QUALITY FACTOR AS A FUNCTION OF ENERGY LOSS PER UNIT DISTANCE IN TISSUE

To calculate the dose equivalent, it is necessary to specify the quality factor as a function of energy loss per unit distance in tissue. For radiation-protection purposes, the quality-factor recommendations of the International Commission on Radiological Protection⁷² are usually used, and it has been recommended by the Radiological Advisory Panel of the Committee on Space Medicine of the National Academy of Sciences, National Research Council, 62 that these same quality factors be used for space-radiation protection purposes.

The quality factor as a function of stopping power, which corresponds to these recommendations and which is used in obtaining the results given later in this report, is shown in Fig. 4.12. The quality factor as a function of stopping power is by assumption independent of particle type, so the values in Fig. 4.12 are to be used for all charged particles.

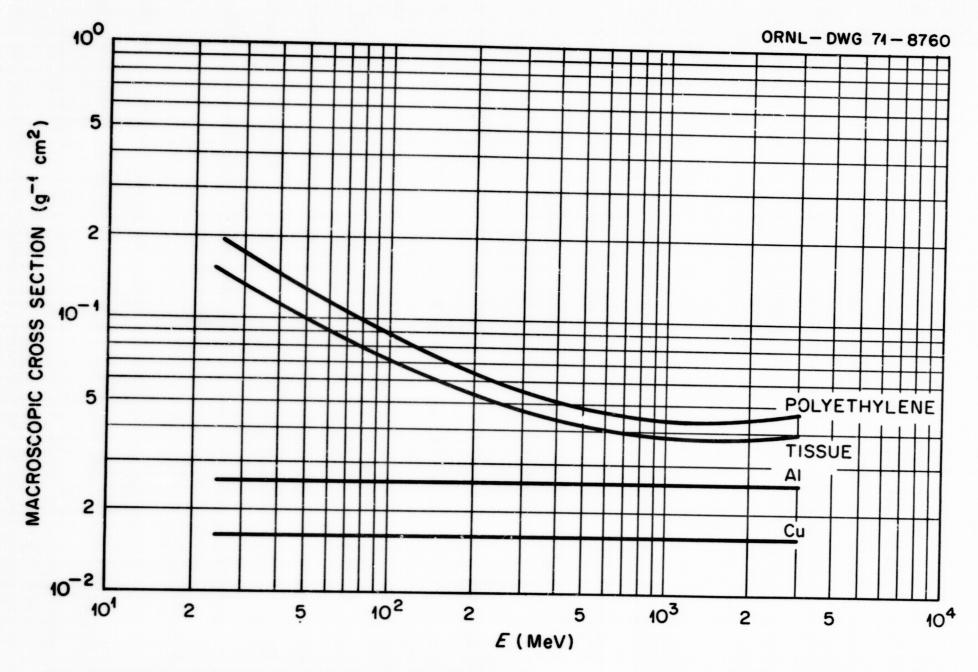


Fig. 4.11. Primary alpha-particle macroscopic nuclear-collision cross section vs energy in various materials.

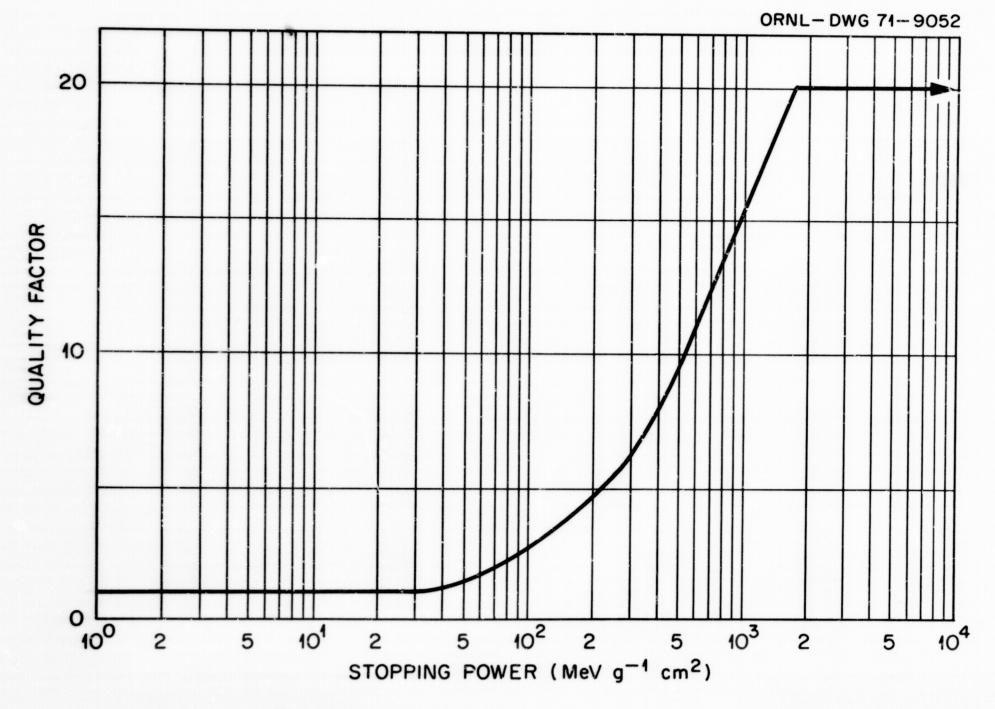


Fig. 4.12. Quality factor vs stopping power.

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Chapter 5

RADIATION PROTECTION GUIDES AND CONSTRAINTS*

Among the more difficult problems encountered in planning manned space-flight missions is the establishment of "acceptable" radiation-protection criteria. This problem has been considered extensively by panels of the Space Science Board of the National Academy of Sciences, National Research Council, 62,94 so only a brief discussion will be given here.

- *The reader who is interested in radiation effects on equipment should see Refs. 95-102 and the many references therein.
- 94. "Radiobiological Factors in Manned Space Flight," W. H. Langham, Ed., National Academy of Sciences, National Research Council, Publication 1487, 1967.
- 95. C. L. Hanks and D. J. Hamman, "Semiconductor Diodes," Section 1 of Radiation Effects Design Handbook, National Aeronautics and Space Administration Report NASA CR-1785, 1971.
- 96. N. J. Broadway, "Thermal-Control Coatings," Section 2 of Radiation Effects Design Handbook, National Aeronautics and Space Administration Report NASA CR-1786, 1971.
- 97. C. L. Hanks and D. J. Hamman, "Electrical Insulating Materials and Capacitors," Section 3 of Radiation Effects Design Handbook, National Aeronautics and Space Administration Report NASA CR-1787, 1971.
- 98. J. E. Drennan and D. J. Hamman, "Transistors," Section 4 of Radiation Effects Design Handbook, National Aeronautics and Space Administration Report NASA CR-1834, 1971.
- 99. M. L. Green and D. J. Hamman, "The Radiations in Space and Their Interactions with Matter," Section 5 of Radiation Effects Design Handbook, National Aeronautics and Space Administration Report NASA CR-1871. 1971.
- 100. J. E. Drennan, "Solid-State Photodevices," Section 6 of Radiation Effects Design Handbook, National Aeronautics and Space Administration Report NASA CR-1872, 1971.
- 101. M. Kangilaski, "Structural Alloys," Section 7 of Radiation Effects Design Handbook, National Aeronautics and Space Administration Report NASA CR-1873, 1971.
- 102. R. H. Herz, The Photographic Action of Ionizing Radiations in Dosimetry and Medical, Industrial, Neutron, Auto- and Micro-Radiography, Wiley-Interscience, New York, 1969.

In Refs. 62 and 94 it is recognized that allowable dose limits cannot be specified without reference to particular space missions and it is recommended that "the radiation protection aspects of each manned space operation should be considered individually in context with a risk-versus-gain philosophy and the magnitude of other risks inherent in the operation."

The radiation effects relevant to a specific mission may roughly be divided into early effects that appear within a few hours to sixty days and late effects that appear within a few to many years. Early effects are highly relevant to both short— and long—range missions in that they may produce sufficient impairment to result in loss of a mission. In mission planning, therefore, it is necessary that the probability of radiation exposure sufficient to produce early effects be quite low regardless of the length of the mission. It is stated in Ref. 94 that in considering early effects a quality factor of unity can be used without serious error, i.e., only the absorbed dose or absorbed—dose rate need be considered, and the known information on the levels of human response as a function of dose and conditions of exposure are discussed.

Late effects have little relevance to short-duration missions but are of significance in long missions and accumulated career exposure. In Ref. 62 the concept of a reference risk is introduced; i.e., the Panel has recommended exposure limits that may "be used as a point of normalization for plans and operations involving different numbers of personnel, different risk-vs-gain evaluations, and different degrees of operational complexity." The reference-risk exposure limits and exposure accumulation-rate constraints are given in Table 5.1. The values in the table are specified in terms of dose equivalent, and the quality-factor recommendations of the

International Commission on Radiological Protection^{72*} are to be used. It must be emphasized that reference-risk recommendations are not to be considered as acceptable or allowable dose limits. It is stated in Ref. 62 that the Panel does not wish to make the judgment that the added risk inherent in the recommendations is "allowable for a given mission or that the added risk is offset by expected gains."

^{*}The quality factor as a function of stopping power is shown in Fig. 4.12.

	Primary Reference Risk (rem at 5 cm)	Ancillary Reference Risks			
		Bone Marrow (rem at 5 cm) b	Skin (rem at 0.1 mm)	Ocular Lens (rem at 3 mm)	Testes (rem at 3 cm)
1-year average daily rate		0.2	0.6	0.3	0.1
30-day maximum		25	75	37	13
Quarterly maximum ^C		35	105	52	18
Yearly maximum		75	225	112	38
Career limit	400	400	1200	600	200

a. Taken from Ref. 62.

120

b. Below skin surface.

c. May be allowed for two consecutive quarters followed by 6 months of restriction from further exposure to maintain yearly limit.

Chapter 6

CALCULATED FLUENCE AND DOSE RESULTS FROM VAN ALLEN BELT AND SOLAR-FLARE SPECTRA

In this chapter a variety of numerical results pertaining to the shielding of space vehicles is presented and discussed. Only incident Van Allen belt and solar-flare spectra are considered. Because of the higher energies involved, the case of galactic cosmic-ray spectra will be treated in Chapter 7. Much of the numerical data presented in this chapter was obtained from the equations of Chapter 3 and from the data of Chapter 4, but absorbed-dose and dose-equivalent results obtained with secondary-particle production and transport properly taken into account are also presented for comparison purposes.

In Section 6.1 a variety of results obtained from primary proton and alpha-particle transport calculations is given and discussed. The data presented were chosen primarily to illustrate various significant features of space-shielding calculations. In Section 6.2 the data obtained with the production and transport of particles from nuclear reaction taken into account are presented. The details of the calculations that include nuclear-reaction products will be found in Appendix 3. In Section 6.3 the validity of neglecting the production and transport of nuclear-reaction products in space-shielding calculations is considered. This is perhaps the most important section in the report since, in general, these nuclear-reaction products must be neglected in space-shielding calculations, and it is in this section that this procedure is to some extent justified. In Section 6.4 the subject of shielding against alpha particles is briefly discussed. In Sections 6.5 and 6.6 the validity of using the equivalent-thickness approximation and the analytic stopping-power approximation, respectively, is

considered. These approximations are primarily intended for use in shielding calculations involving very complex geometries. However, the results indicate that the equivalent-thickness approximation is quite reliable, and it is sufficiently simple to use that it may be useful even when relatively simple geometries are being considered. In Section 6.7 results obtained with the codes MEVDP⁷⁵ and LSVDC4, ⁷⁸ which are capable of treating very complex geometries, are presented and compared.

6.1 PRIMARY PROTON AND ALPHA-PARTICLE TRANSPORT CALCULATIONS

The large majority of the primary proton and alpha-particle transport calculations presented in this report have been carried out with the computer code TRAPP. 103 By means of numerical integration of the equations given in Chapter 3, this code calculates the primary-particle fluences and doses at the center of the tissue sphere in the geometry shown in Fig. 3.1.* The code gives the absorbed dose and the dose equivalent from both the attenuated and unattenuated fluences.

In the majority of cases reported here, the radius of the tissue sphere, r_T , was taken to be 15 g cm⁻², but for illustrative purposes some results are also presented for the case of $r_T=0$. It is to be understood that when $r_T=0$, an infinitesimal tissue sphere in which the doses are calculated is still assumed to be present. It should also be noted that when the straightahead approximation is used and the results are calculated only at

^{*}The code calculates the particle flux at the center of the tissue sphere if flux is incident as in the Van Allen belt, and it calculates the fluence at the center of the tissue sphere, i.e., the time-integrated flux, if fluence is incident as in the case of a solar flare. If flux is calculated, then the dose rate is also calculated; if fluence is calculated, then the dose is obtained.

^{103.} J. Barish, R. T. Santoro, F. S. Alsmiller, and R. G. Alsmiller, Jr., "TRAPP, a Computer Program for the Transport of Alpha Particles and Protons with All Nuclear-Reaction Products Neglected," Oak Ridge National Laboratory Report ORNL-4763, 1972.

the center of the sphere as in TRAPP, the shield thickness but not the shield radius enters into the computation; i.e., for calculations with TRAPP the radius of the vacuum gap as shown in Fig. 3.1 is irrelevant.

The physical data used in all of the calculations are those described in Chapter 4. The incident spectra used are those given in Sections 2.1.5 and 2.2.2 of Chapter 2. In particular, the normalization in the Van Allen belt spectra is that given in Table 2.1, and it is assumed that there are no incident Van Allen belt protons with energies > 1000 MeV. All incident proton and alpha-particle solar-flare spectra are normalized to 10⁹ particles/cm² with energies between 30 and 3000 MeV, and it is assumed that there are no incident solar-flare particles with energies > 3000 MeV.

6.1.1 Primary Proton and Alpha-Particle Fluence as a Function of Shield Thickness

It is instructive to consider how the primary-particle flux or fluence per unit energy changes as a function of shield thickness. The proton flux per unit energy is shown in Fig. 6.1 as a function of energy at the center of the shield for various shield thicknesses for the case of a Van Allen belt proton spectrum, corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° , isotropically incident on a polyethylene shield. In obtaining the results shown in Fig. 6.1, attenuation due to nuclear collisions has been neglected, i.e., $\sigma_{\rm Sp} = \sigma_{\rm Tp} = 0$, and the radius of the tissue sphere, $r_{\rm T}$, has been taken to be zero. The incident spectrum, $r_{\rm S} \approx 0$, in Fig. 6.1 is not shown below 30 MeV because in all calculations incident protons with energies < 30 MeV are not considered. This is justified because the range of 30-MeV protons in all materials considered is less than the smallest shield thickness considered; i.e., the flux per unit energy shown in Fig. 6.1 at a shield thickness of 2 g cm⁻² would not be

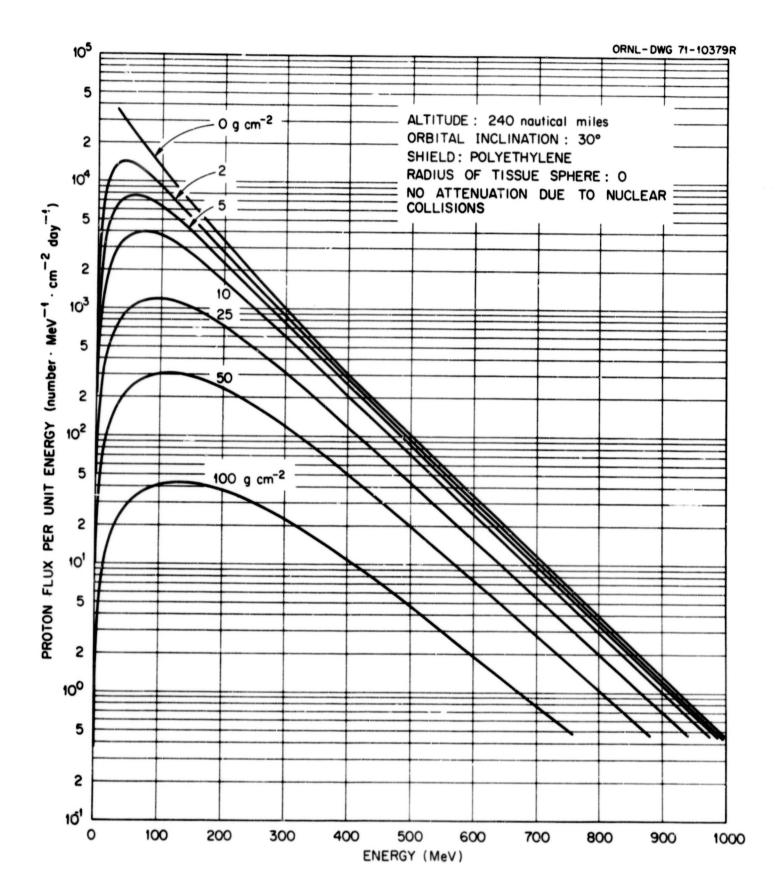


Fig. 6.1. Proton flux per unit energy at the center of the shield vs energy for a proton spectrum, corresponding to a circular orbit in the Van Allen belt, isotropically incident on spherical shell shields of various thicknesses.

changed even if protons with energies < 30 MeV were included in the incident spectrum. At shield thicknesses of 2 g cm⁻² and greater, all of the curves in Fig. 6.1 exhibit a peak at energies of the order of 150 MeV or less. As the shield thickness increases, the proton energy at which the peak occurs becomes larger and the peak becomes broader. This peak is due to the very rapid increase in the proton stopping power at very low energies. It should be noted that the maximum proton energy in the flux per unit energy is a function of shield thickness. In the figure there are no protons above the highest energy at which the curve corresponding to a given shield thickness is plotted; i.e., since the maximum incident proton energy is 1000 MeV, there is a maximum energy proton at each depth corresponding to the energy a 1000-MeV proton will have after traversing the specified shield thickness. In Fig. 6.1 the decrease of the flux per unit energy as shield thickness increases is due entirely to the form of the incident spectrum and proton slowing-down since the attenuation due to nuclear collisions has been neglected; i.e., the lower energy particles that were most numerous in the incident spectrum reach the end of their range as the shield thickness increases, and the particles that remain are the slowed-down higher energy incident particles.

The proton flux per unit energy is shown in Fig. 6.2 as a function of energy for the same case as that shown in Fig. 6.1 except that the tissue sphere $(r_T = 15 \text{ g cm}^{-2})$ has been included in the calculations. In Fig. 6.2, as in Fig. 6.1, attenuation due to nuclear collisions has been neglected; i.e., $\sigma_{Sp} = \sigma_{Tp} = 0$. The curves in Fig. 6.2 show the same general features as those in Fig. 6.1, but the magnitude of the flux per unit energy at a given shield thickness in Fig. 6.2 is less than that in Fig. 6.1 because in

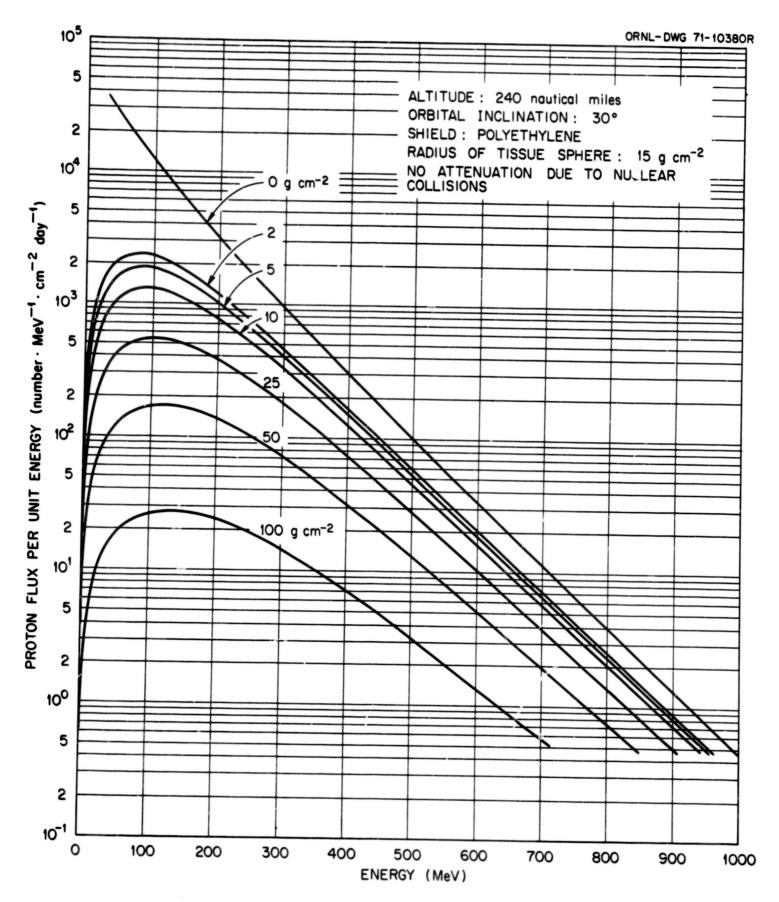


Fig. 6.2. Proton flux per unit energy at the center of the tissue sphere vs energy for a proton spectrum, corresponding to a circular orbit in the Van Allen belt, isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

Fig. 6.2 the particles have been slowed down by passing through the additional 15 g $\,\mathrm{cm}^{-2}$ of tissue.

The proton fluence per unit energy is shown in Figs. 6.3 and 6.4 as a function of energy at the center of the shield for various shield thicknesses for the case of a solar-flare proton spectrum with a characteristic rigidity of 100 MV isotropically incident on an aluminum shield. The results in Fig. 6.3 differ from those in Fig. 6.4 in that in Fig. 6.3 the radius of the tissue sphere, r_T , has been taken to be zero, while in Fig. 6.4 $r_T = 15 \ \mathrm{g \ cm^{-2}}$. The curves in Figs. 6.3 and 6.4 exhibit the same general behavior as those in Figs. 6.1 and 6.2, but they extend to higher energies since in the case of solar flares incident energies of 3000 MeV are considered. Above approximately 1000 MeV, the shape of the proton fluence per unit energy is not very dependent on shield thickness. Because of the very rapid decrease in the fluence per unit energy as energy increases, it is clear that the higher energy (\geq 1000 MeV) protons will not contribute appreciably to the absorbed dose or dose equivalent for the shield thickness considered.

The alpha-particle fluence per unit energy is shown in Figs. 6.5 and 6.6 as a function of energy at the center of the shield for various shield thicknesses for the case of a solar-flare alpha-particle spectrum with a characteristic rigidity of 100 MV isotropically incident on an aluminum shield. In Fig. 6.5 $r_T = 0$ and in Fig. 6.6 $r_T = 15$ g cm⁻². In both Figs. 6.5 and 6.6 the attenuation due to nuclear collisions has been neglected, so $\sigma_{S\alpha} = \sigma_{T\alpha} = 0$. The alpha-particle curves in Figs. 6.5 and 6.6 exhibit the same general features as the proton curves in Figs. 6.3 and 6.4, but these features are emphasized because of the larger alpha-particle stopping power.

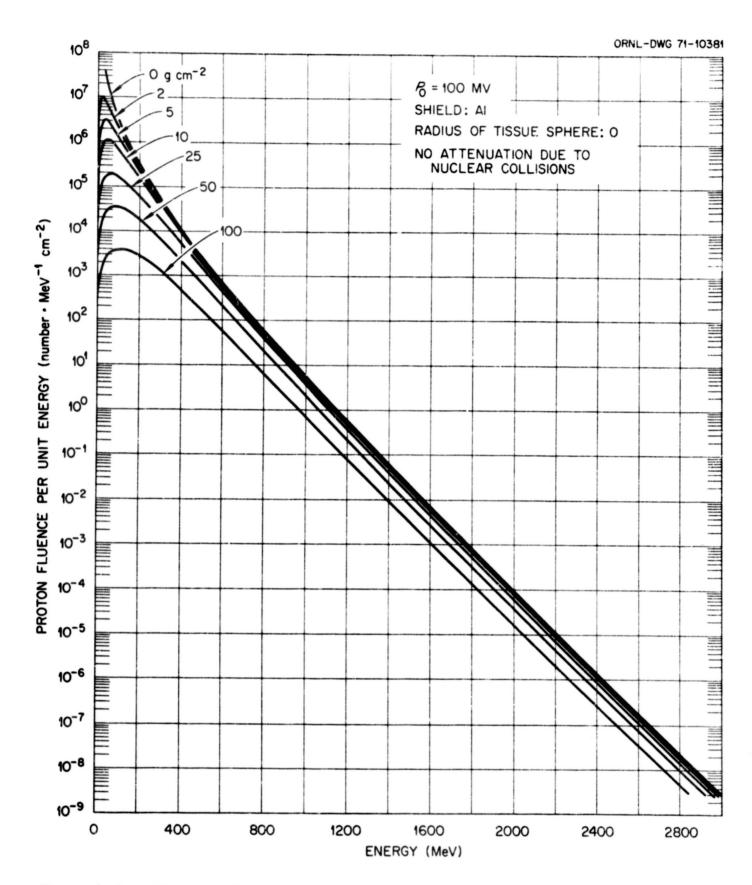


Fig. 6.3. Proton fluence per unit energy at the center of the shield vs energy for a solar-flare proton spectrum isotropically incident on spherical shell shields of various thicknesses.

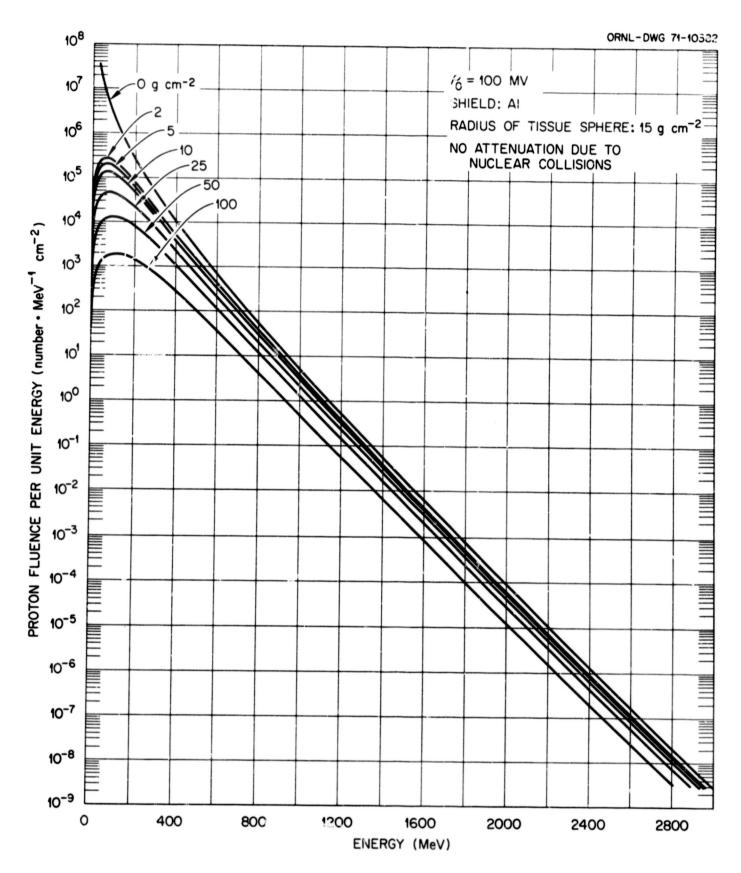


Fig. 6.4. Proton fluence per unit energy at the center of the tissue sphere vs energy for a solar-flare proton spectrum isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

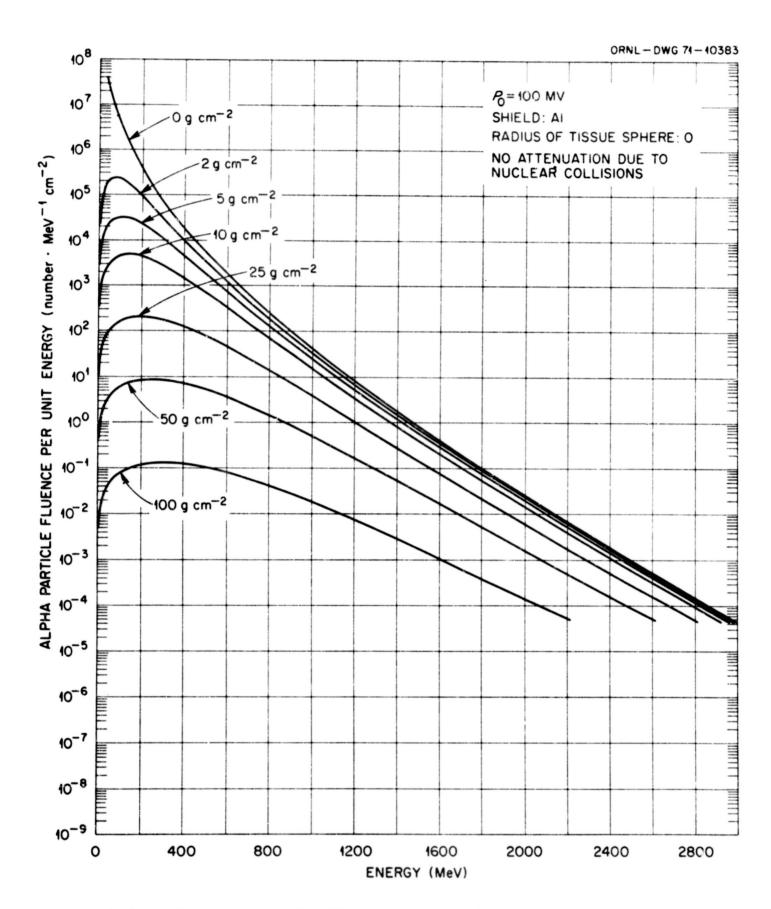


Fig. 6.5. Alpha-particle fluence per unit energy at the center of the shield vs energy for a solar-flare alpha-particle spectrum isotropically incident on spherical shell shields of various thicknesses.

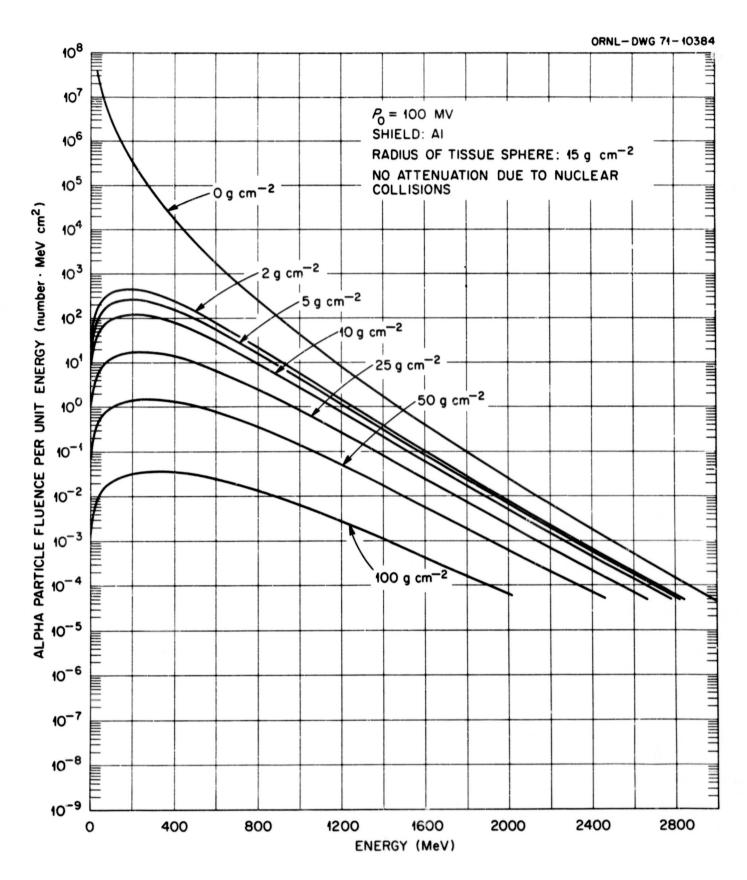


Fig. 6.6. Alpha-particle fluence per unit energy at the center of the tissue sphere vs energy for a solar-flare alpha-particle spectrum isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

Note particularly the very rapid change in the low-energy part of the incident alpha-particle spectrum that is caused by the 2-g-cm⁻²-thick aluminum shield, as shown in Fig. 6.5. At all shield thicknesses, but particularly at the larger thicknesses, the peaks in the alpha-particle fluence per unit energy are much less pronounced and occur at higher energies than the corresponding peaks in the proton fluence per unit energy.

All of the results shown in Figs. 6.1 to 6.6 were obtained with the attenuation due to nuclear collisions neglected. When nuclear attenuation is included, the flux or fluence per unit energy at a given shield thickness is decreased, but the shape of the curves is not changed appreciably. illustrate this, the attenuated and unattenuated proton flux per unit energy at the center of the tissue sphere is shown in Fig. 6.7 as a function of energy for several polyethylene shield thicknesses for the case of a Van Allen belt proton spectrum, corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° , isotropically incident on a spherical shell shield. In Figs. 6.8 and 6.9 similar results are shown for the case of a solar-flare proton and alpha-particle spectrum with characteristic rigidity of 100 MV incident on an aluminum shield. In Figs. 6.7 to 6.9 the solid-line curves show the results when nuclear attenuation is neglected and the dashed-line curves show the results when nuclear attenuation is included. For a given shield thickness, the solid- and dashed-line curves in each individual figure have nearly the same shape. The effect of nuclear collisions in the case of alpha particles is more pronounced than in the case of protons because the alpha-particle-collision cross section is larger than the proton-collision cross section.

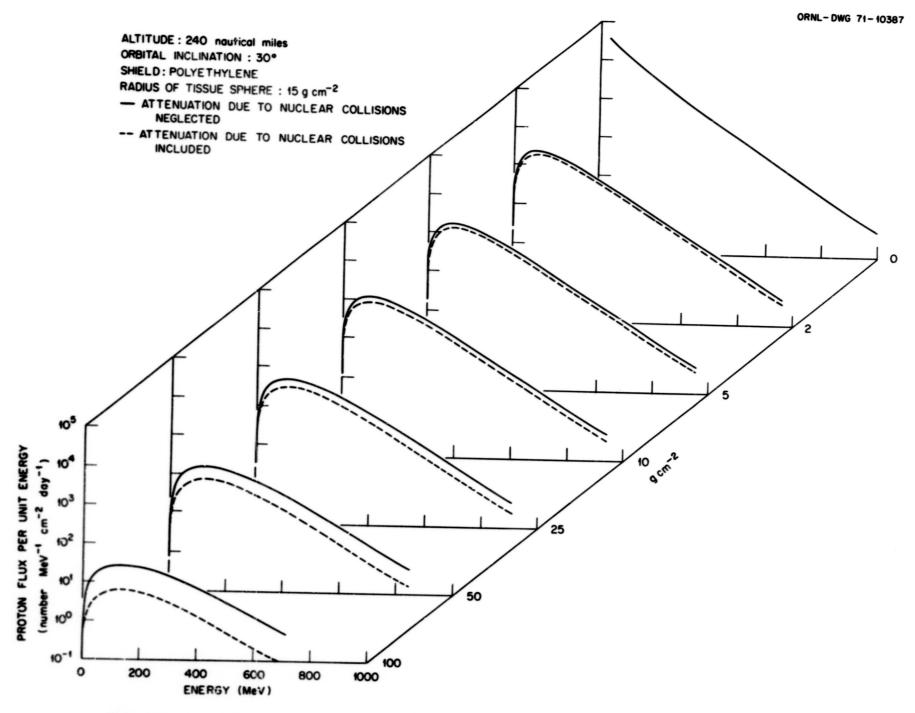


Fig. 6.7. Proton flux per unit energy at the center of the tissue sphere vs energy for a proton spectrum, corresponding to a circular orbit in the Van Allen belt, isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

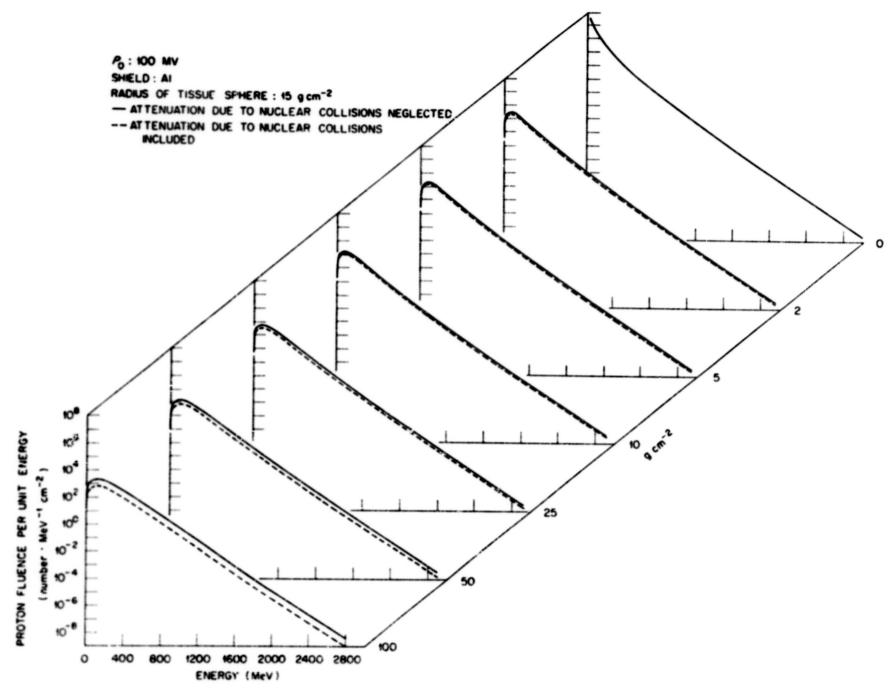


Fig. 6.8. Proton fluence per unit energy at the center of the tissue sphere vs energy for a solar-flare proton spectrum isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

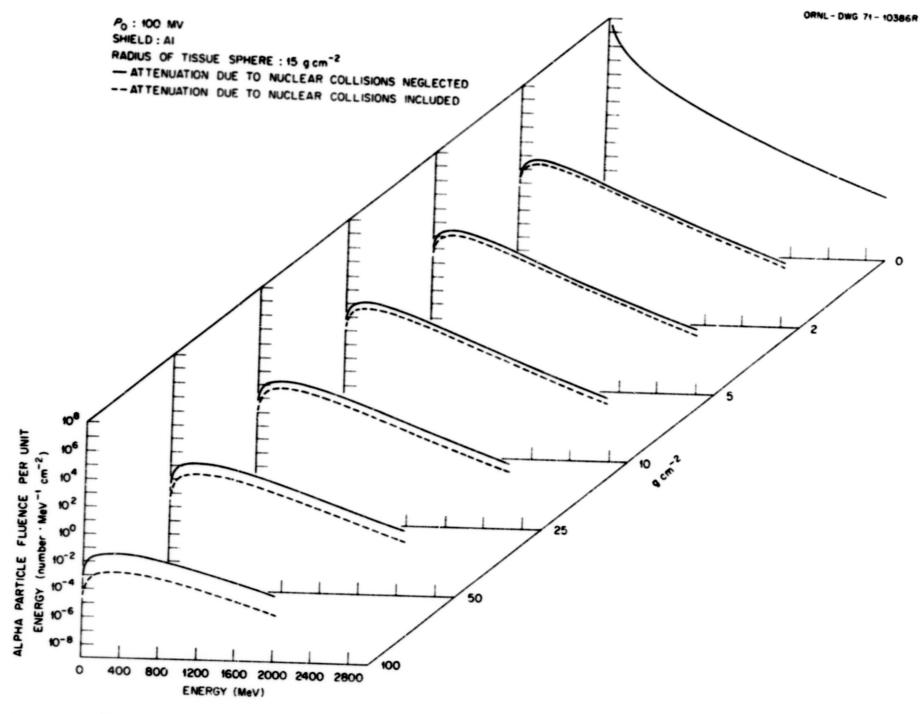


Fig. 6.9. Alpha-particle fluence per unit energy at the center of the tissue sphere for a solar-flare alpha-particle spectrum isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

For other incident solar-flare and Van Allen belt spectra and for other shield materials, results similar to those shown in Figs. 6.1 to 6.9 would be obtained.

6.1.2 Primary Proton and Alpha-Particle Absorbed Dose and Dose Equivalent as a Function of Shield Thickness

The calculation of the primary-particle absorbed-dose rate (or absorbed dose) and dose-equivalent rate (or dose equivalent) is a straightforward matter of numerical integration once the primary-particle flux (or fluence) per unit energy is calculated. One minor difficulty arises in that the dose integrals extend to zero energy and, because of the lack of information concerning the stopping powers of very low energy particles, the flux (or fluence) per unit energy is usually known above some low-energy cutoff. This causes no essential problem because it is an excellent approximation to neglect the contribution to the dose integrals of the very low energy particles since their range is very small compared to the shield thicknesses of interest; that is, the error caused by neglecting the contribution to the dose integrals at a particular shield thickness by particles below some specific energy E' is of the order of the error that would be caused by adding the range of a particle of energy E' to the shield thickness. In all of the calculations carried out with TRAPP and reported here, it has been assumed that both protons and alpha particles with energies < 0.1 MeV may be neglected.

Before considering the dose values due to the various incident-particle spectra, it is instructive to consider the integrands that occur in the dose integrals (Eqs. 3.17 and 3.18) because in this manner an estimate of the particle energies that actually contribute to the absorbed-dose and dose-equivalent rates can be obtained.

The integrand in the absorbed-dose-rate integral (Eq. 3.17), i.e., the proton flux per unit energy multiplied by the stopping power of tissue for protons, is shown in Fig. 6.10 as a function of energy at the center of the tissue sphere for the case of a Van Allen belt proton spectrum, corresponding to an altitude of 240 nautical miles and an orbital inclination of 30°, isotropically incident on various thicknesses of a polyethylene shield. The integrand in the dose-equivalent-rate integral (Eq. 3.18), i.e., the proton flux per unit energy multiplied by the stopping power of tissue for protons and multiplied by the quality factor, is shown in Fig. 6.11 as a function of energy for the same case as that considered in Fig. 6.10. In both Figs. 6.10 and 6.11 the attenuation due to nuclear collisions has been neglected.

In Fig. 6.10 the curves show a marked difference from the flux-per-unitenergy curves in Fig. 6.1 in that they do not have a peak but are monotone decreasing as the particle energy increases. This difference arises because the values shown in Fig. 6.10 are a product of the flux per unit energy and the tissue stopping power, and at low energies the flux per unit energy decreases as energy decreases but the stopping power increases as energy decreases. It is clear from the curves in Fig. 6.10 that protons of the order of 100 MeV and less are the major contributors to the absorbeddose rate.

The curves in Fig. 6.11 differ from those in Fig. 6.10 in that the quality factor has been included. For protons, the quality factor is not appreciably different from unity at energies above 15 MeV, and therefore the curves in Fig. 6.11 are the same as those in Fig. 6.10 at energies above 15 MeV. Below this energy, however, the quality factor increases rapidly with decreasing energy, and this is responsible for the abrupt increase in

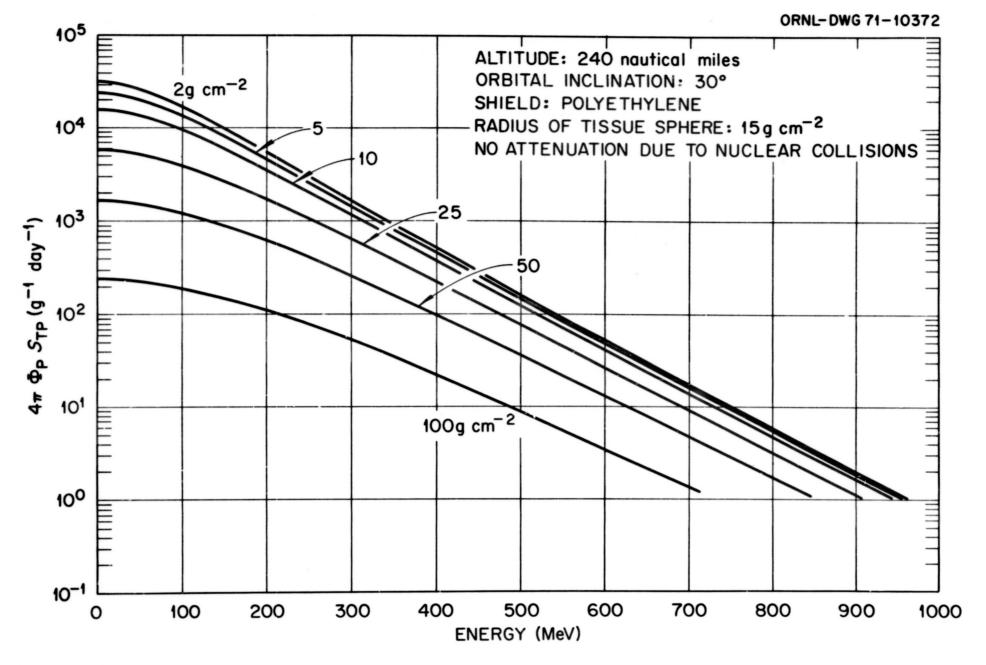


Fig. 6.10. Integrand of the absorbed-dose-rate integral, Eq. 3.17, vs energy for a proton spectrum, corresponding to a circular orbit in the Van Allen belt, isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

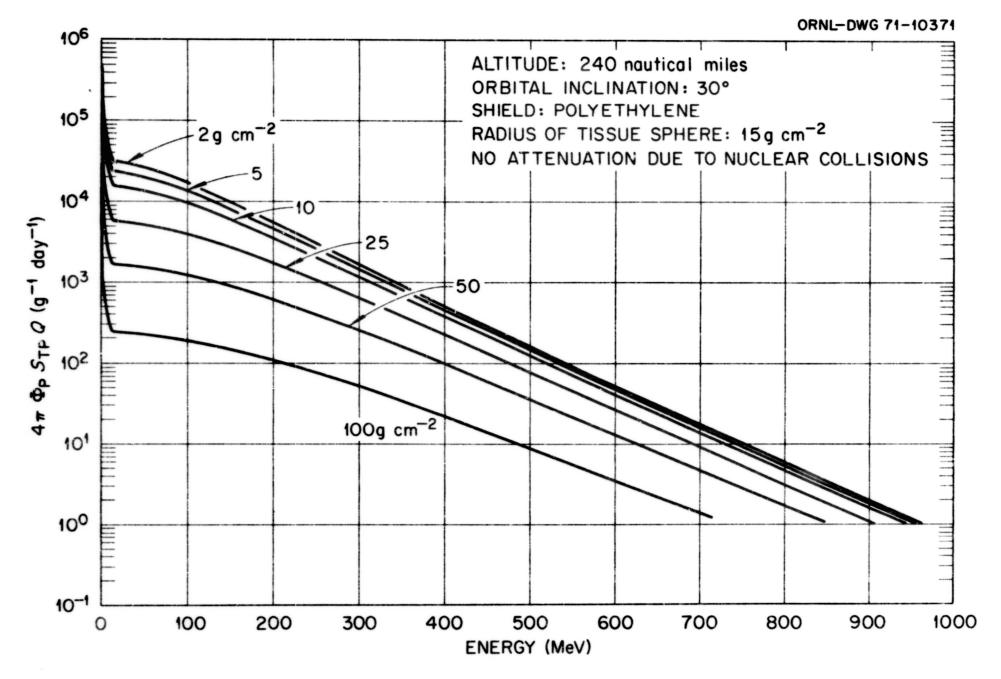


Fig. 6.11. Integrand of the dose-equivalent-rate integral, Eq. 3.18, vs energy for a proton spectrum, corresponding to a circular orbit in the Van Allen belt, isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

the curves in Fig. 6.11 at energies below 15 MeV. For a given shield thickness, the absorbed-dose rate and the dose-equivalent rate are obtained by integrating under the appropriate curve in Figs. 6.10 and 6.11. Since the corresponding curves in Figs. 6.10 and 6.11 are the same above 15 MeV, it is only the differences below 15 MeV that account for the difference between the absorbed-dose rate and the dose-equivalent rate for a given shield thickness.

The integrands in Eqs. 3.17 and 3.18, respectively, are shown in Figs. 6.12 and 6.13 as a function of energy at the center of the tissue sphere for a solar-flare proton spectrum with a characteristic rigidity of 100 MV isotropically incident on various thicknesses of an aluminum shield. The curves in Figs. 6.12 and 6.13 have the same general features as those in Figs. 6.10 and 6.11.

The integrands in Eqs. 3.17 and 3.18, respectively, are shown in Figs. 6.14 and 6.15 as a function of energy at the center of the tissue sphere for a solar-flare alpha-particle spectrum with a characteristic rigidity of 100 MV isotropically incident on various thicknesses of an aluminum shield. In Figs. 6.14 and 6.15 the attenuation due to nuclear collisions has been neglected. In Fig. 6.14 the curves of alpha-particle fluence multiplied by the tissue stopping power are monotone, decreasing with increasing energy as in the case of the protons in Fig. 6.12, but the alpha-particle curves decrease much less rapidly than the proton curves as energy increases. Therefore, the higher energy (of the order of a few hundred MeV) alpha particles contribute more to the alpha-particle absorbed dose than the higher energy protons contribute to the proton absorbed dose.

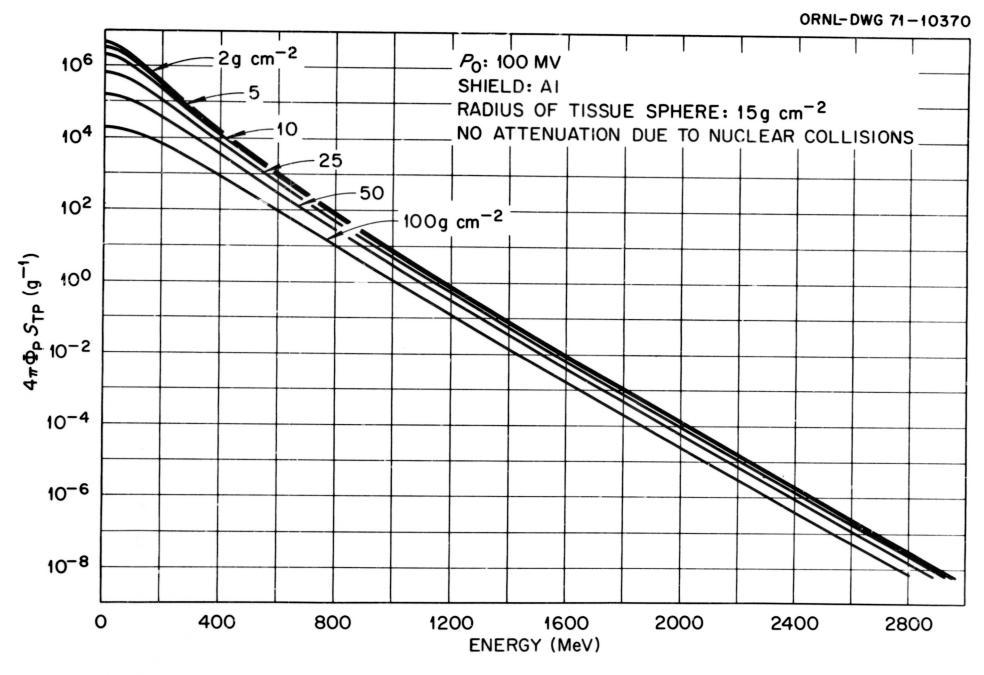


Fig. 6.12. Integrand of the absorbed-dose integral, Eq. 3.17, vs energy for a solar-flare proton spectrum isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

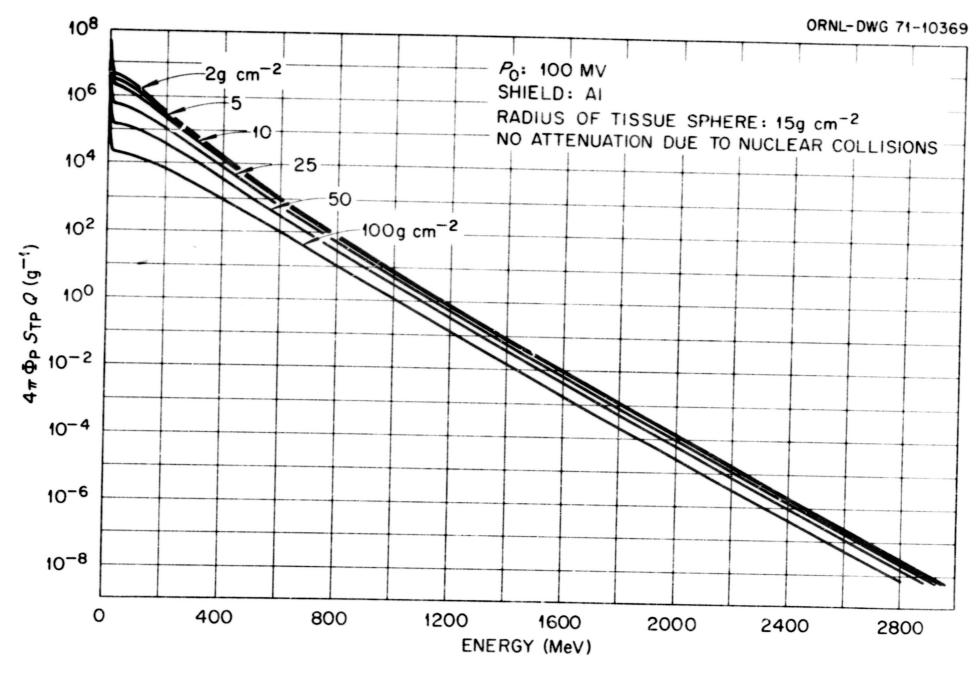


Fig. 6.13. Integrand of the dose-equivalent integral, Eq. 3.18, vs energy for a solar-flare proton spectrum isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the $15 \ g \ cm^{-2}$ of tissue.

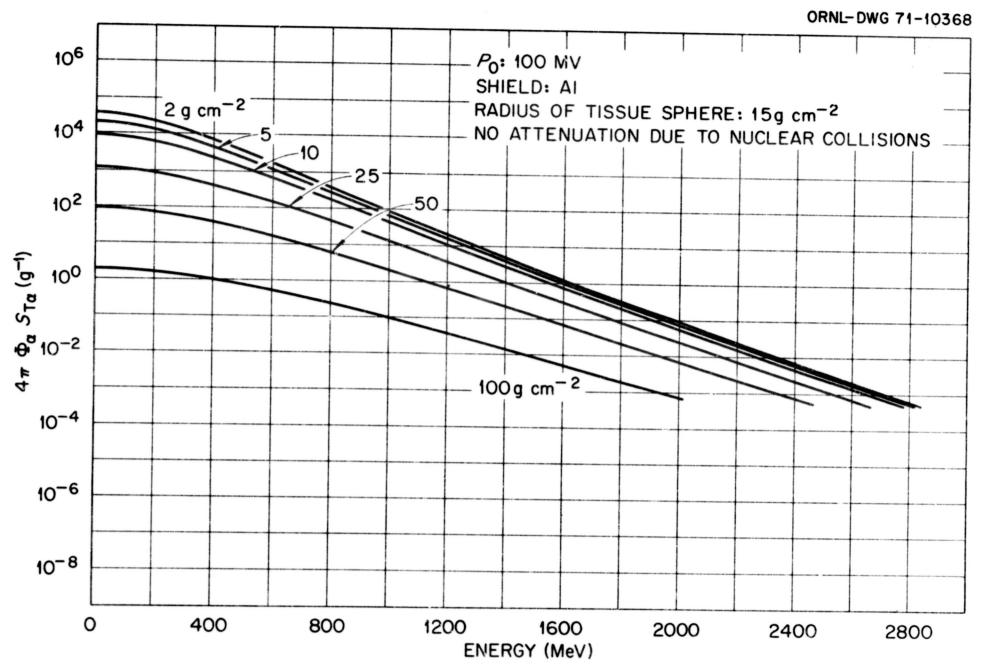


Fig. 6.14. Integrand of the absorbed-dose integral, Eq. 3.17, vs energy for a solar-flare alpha-particle spectrum isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the 15 g cm⁻² of tissue.

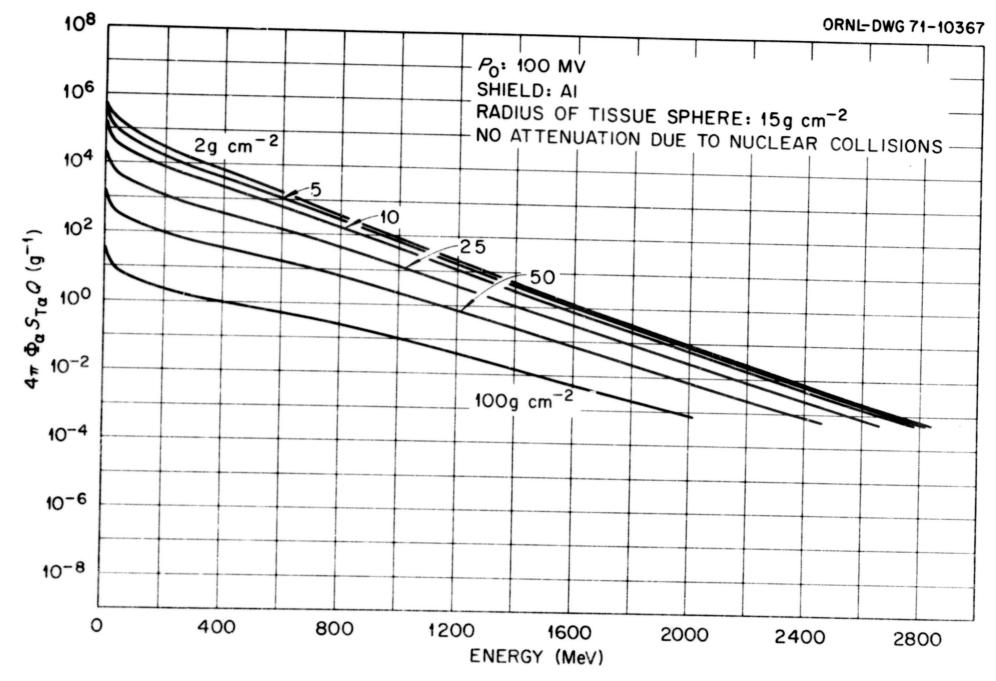


Fig. 6.15. Integrand of the absorbed-dose integral, Eq. 3.17, vs energy for a solar-flare alpha-particle spectrum isotropically incident on spherical shell shields of various thicknesses. The thickness specified on each curve is the shield thickness only; i.e., the values given do not include the $15~{\rm g~cm^{-2}}$ of tissue.

The curves in Fig. 6.15 differ from those in Fig. 6.14 in that the quality factor has been included. For alpha particles the quality factor is not appreciably different from unity at energies > 300 MeV, and therefore the curves in Fig. 6.15 are the same as those in Fig. 6.14 above this energy. Since the quality factor for alpha particles is different from unity at energies < 300 MeV whereas the quality factor for protons is different from unity only at energies < 15 MeV, it is to be anticipated that the difference between the absorbed dose and dose equivalent for alpha particles will be larger than the difference between the absorbed dose and dose equivalent for protons.

For the cases considered in Figs. 6.10 to 6.15, the various doses are shown in Fig. 6.16 as a function of shield thickness. The values shown correspond to the doses at the center of a 15-g-cm⁻²-radius tissue sphere (see Fig. 3.1). The solid-line curves give the dose-equivalent rate or dose equivalent as a function of shield thickness and the dashed-line curves give the absorbed-dose rate or absorbed dose as a function of shield thickness. Results are shown in Fig. 6.16 with the attenuation due to nuclear collisions both included and neglected. For all cases shown, the corresponding solidand dashed-line curves have approximately the same shape, so the ratio of the dose equivalent rate to the absorbed-dose rate, or the dose equivalent to the absorbed dose, is not strongly dependent on shield thickness. These ratios are also approximately independent of whether or not nuclear attenuation is included in the calculations. In the case of protons, the doseequivalent rate or dose equivalent is only slightly larger than the absorbeddose rate or absorbed dose, but in the case of alpha particles the dose equivalent is appreciably larger than the absorbed dose.

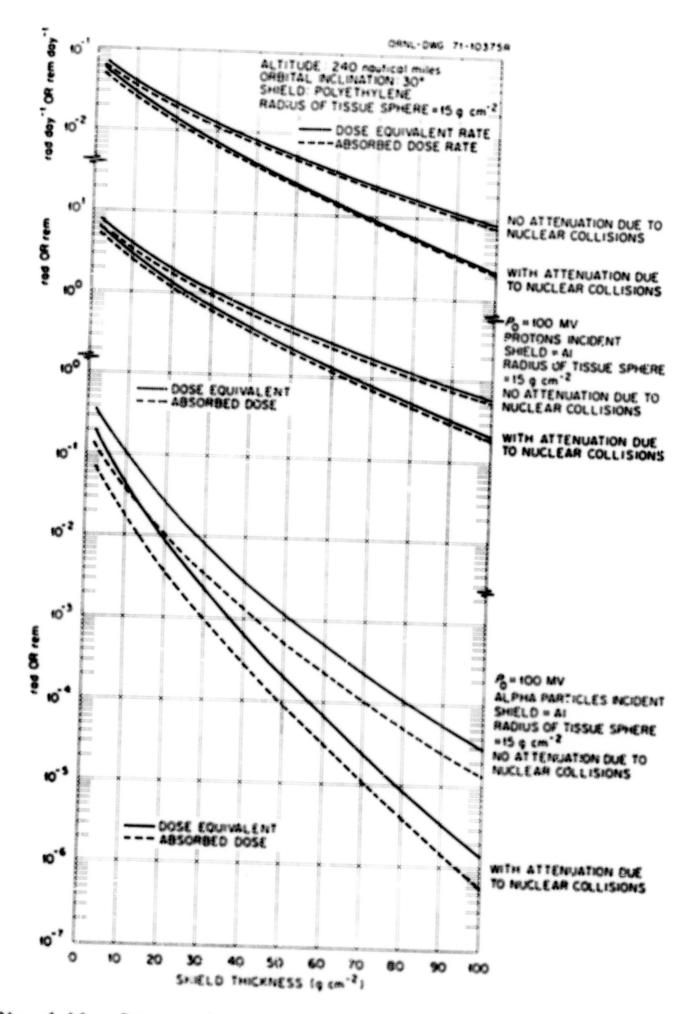


Fig. 6.16. Dose or dose rate from only primary particles at the center of a tissue sphere vs sphericall-shell-shield thickness for various incident-particle spectra.

The effect of nuclear attenuation on the various doses increases with shield thickness and becomes very large at the largest shield thicknesses considered. The effect of nuclear attenuation is considerably larger in the case of incident alpha particles than in the case of incident protons.

The various doses are shown in Fig. 6.17 as a function of shield thickness for tissue spheres with radii of 0 and 15 g cm⁻². The incident spectra and shield materials are the same as those considered in Fig. 6.16. All of the results shown in Fig. 6.17 were obtained with the attenuation due to nuclear collisions neglected. The curves in Fig. 6.17 indicate that the presence of the tissue sphere has an appreciable effect on the doses, particularly for small shield thicknesses and for incident alpha particles. This is to be expected since the presence of the tissue effectively increases the shield thickness. In fact, much of the difference between the corresponding curves in Fig. 6.17, i.e., the curves for a given type dose with tissue sphere radii of 0 and 15 g cm⁻², would be removed if the results were plotted against shield thickness plus tissue-sphere radius rather than against shield thickness. The subject of primary-particle doses at the center of the shield for tissue-sphere radii of 0 and 15 g cm⁻² is discussed in more detail in Section 6.3.2.

The quantitative results presented in this section are dependent on the incident spectra and shield materials considered, but most of the discussion is applicable to other Van Allen belt and solar-flare spectra and to other shield materials. In Appendix 2 dose values analogous to those shown in Figs. 6.16 and 6.17 are presented for a large variety of Van Allen belt and solar-flare spectra and for shields of aluminum, polyethylene, and copper.

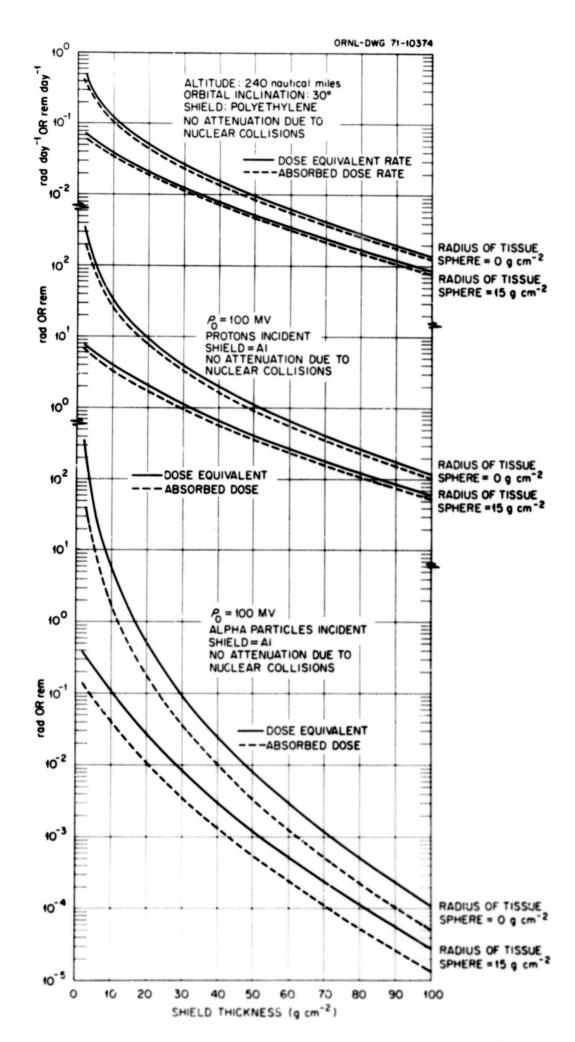


Fig. 6.17. Dose or dose rate from only primary particles at the center of a tissue sphere vs spherical-shell-shield thickness for various incident-particle spectra. Results are shown for tissue sphere radii of 0 and 15 g cm⁻².

6.2 THE SECONDARY-PARTICLE CONTRIBUTION TO THE ABSORBED DOSE AND DOSE EQUIVALENT FOR INCIDENT PROTON SPECTRA

Space-shielding calculations that include the production of secondary particles from nuclear collisions and the transport of these particles are very complex and too time-consuming to be carried out on a routine basis. However, a computer code, NMTC, 69 capable of carrying out such calculations for incident protons is available, and therefore estimates of the secondaryparticle contribution to the absorbed dose and dose equivalent in typical cases can be obtained. Calculated results obtained with NMTC have been compared with a variety of experimental data, and, in general, good agreement has been obtained. 104-106 In this section the results of calculations carried out with NMTC for the geometry shown in Fig. 3.1 and $r_{\rm T}$ = 15 g cm⁻² are presented and discussed.* It should be noted that since secondary particles are explicitly included in the calculations the results presented in this section are not independent of the radius of the vacuum gap shown in Fig. 3.1. The details of the calculations are described in Appendix 3. In Section 6.3 the calculated results presented here are used to test the validity of the very approximate method of including secondary particles described in Section 3.4.

^{*}A general discussion of the inclusion of secondary-particle production and transport in space-shielding calculations will be found elsewhere. 68

^{104.} W. A. Coleman and R. G. Alsmiller, Jr., "Thermal-Neutron Flux Generation by High-Energy Protons," Nucl. Sci. Eng. 34, 104 (1968).

^{105.} T. W. Armstrong and R. G. Alsmiller, Jr., "Monte Carlo Calculations of the Nucleon-Meson Cascade in Iron Initiated by 1- and 3-GeV Protons and Comparison with Experiment," Nucl. Sci. Eng. 33, 291 (1968).

^{106.} T. W. Armstrong and B. L. Bishop, "Calculation of the Absorbed Dose and Dose Equivalent Induced by Medium-Energy Neutrons and Protons and Comparison with Experiment," Radiat. Res. 47, 581 (1971).

In shielding calculations which include secondary-particle production and transport, there are many different kinds of particles, each of which contribute to the absorbed dose and dose equivalent. The individual contributions to the absorbed-dose rate are shown in Fig. 6.18 as a function of depth in the tissue for a Van Allen belt proton spectrum, corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° , isotropically incident on a 20-g-cm⁻²-thick aluminum shield. In the figure, the histogram labeled "primary protons" gives the dose rate due to the ionization and excitation of atomic electrons by those incident protons that have not suffered a nuclear interaction. In the Monte Carlo calculations, the nuclear cross sections are defined in the same manner as they were defined in Chapter 3, so the primary-proton curve in Fig. 6.18 corresponds to the attenuated primary-proton dose rate. The histogram labeled "secondary protons" gives the absorbed-dose rate from the ionization and excitation of atomic electrons by protons produced from nonelastic nucleon- and pion-nucleus collisions in the shield and in the tissue and from the elastic collisions of nucleons and pions with hydrogen nuclei in the tissue. The histogram labeled "heavy nuclei" gives the absorbed-dose rate from particles with mass number greater than unity produced from nonelastic nucleon-nucleus and pionnucleus collisions and the absorbed-dose rate from recoiling nuclei produced from elastic neutron-nucleus collisions and nonelastic nucleon-nucleus and pion-nucleus collisions. The histogram labeled "charged pions" gives the absorbed-dose rate from the excitation and ionization of atomic electrons by both positively and negatively charged pions produced from nucleon-nucleus The histogram labeled "photons from neutral and pion-nucleus collisions. pions" gives the absorbed-dose rate produced by the photons arising from the

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- **X MUONS**

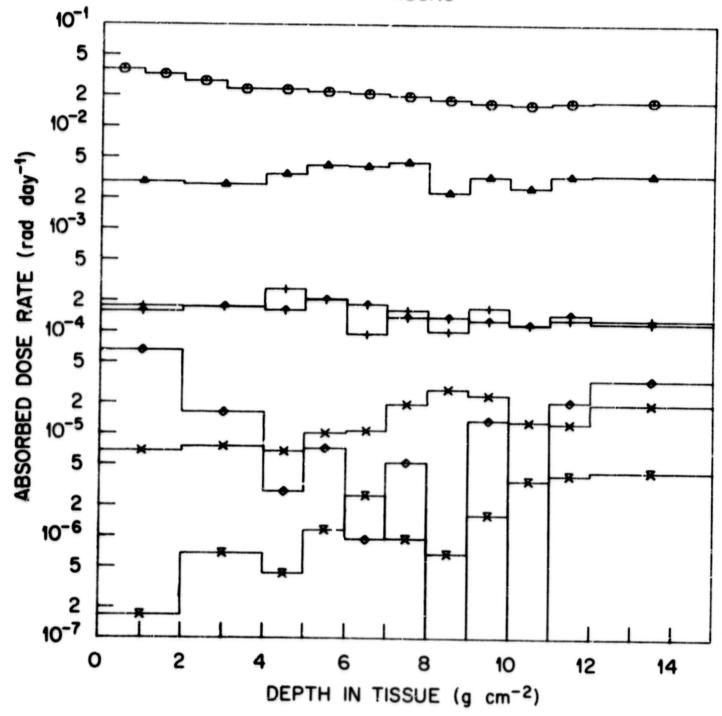


Fig. 6.18. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt proton spectrum corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° is isotropically incident on a $20\text{-g-cm}^{-2}\text{-thick}$ aluminum shield (see Fig. 3.1).

decay of neutral pions. The histogram labeled "electrons, positrons, and photons" gives the absorbed-dose rate from electrons and positrons produced by muon decay, and the absorbed-dose rate from the photons produced by nucleon-nucleus and pion-nucleus nonelastic collisions. In the calculations, the approximation was made that photons, electrons, and positrons deposit their energy at their point of origin; i.e., these particles have not been transported. The histogram labeled "muons" gives the absorbed-dose rate from the ionization and excitation of atomic electrons by both positively and negatively charged muons. A dose contribution from secondary neutrons is not shown since neutrons contribute to the dose rate only by producing charged particles from nuclear collisions, and the contributions of these charged particles are included in the other categories.

The total absorbed-dose rate is obtained by adding all of the contributions shown in Fig. 6.18. Since the calculations have been carried out by Monte Carlo methods, the results are subject to statistical fluctuations as evidenced by the somewhat erratic behavior of some of the individual histograms. This is particularly noticeable with those categores that contribute only a very small amount to the total absorbed-dose rate, but this is relatively unimportant because a large uncertainty in such a small quantity does not introduce any appreciable uncertainty in the total absorbed-dose rate. The only appreciable contribution to the total absorbed-dose rate at all tissue depths in Fig. 6.18 is from primary and secondary protons. The primary-proton dose rate decreases slightly as the tissue depth increases but the secondary-proton dose rate is, within the statistical uncertainties, relatively constant as a function of tissue depth.

The individual contributions to the dose-equivalent rate for the same case as that considered in Fig. 6.18 are shown in Fig. 6.19. The individual histograms in Fig. 6.19 have the same meanings as those in Fig. 6.18. The major contributions to the dose-equivalent rate are from primary and secondary protons and from heavy nuclei. The fact that the heavy nuclei contribute appreciably to the dose-equivalent rate and not to the absorbed-dose rate is due to the large quality factor (20) that is associated with energy deposition by all heavy nuclei.

The contributions to the absorbed dose and dose equivalent, respective—
ly, from the various types of particles are shown in Figs. 6.20 and 6.21 as
a function of depth in tissue for the case of a solar-flare proton spectrum
with a characteristic rigidity of 100 MV isotropically incident on a 20-g-cm⁻²thick shield of polyethylene. The contributions in the figures have the same
meanings as those in Figs. 6.18 and 6.19. In Figs. 6.20 and 6.21, as in
Figs. 6.18 and 6.19, the primary and secondary protons are the major contributors to the absorbed dose, and the primary and secondary protons and
heavy nuclei are the major contributors to the dose equivalent.

The magnitude of the contribution of the various types of particles to the absorbed dose or absorbed-dose rate and the dose equivalent or dose-equivalent rate is dependent on the incident-particle spectrum, shield thickness, and shield material, but the results for the other cases considered later in this section are qualitatively similar to those shown in Figs. 6.18 to 6.21. Figures analogous to Figs. 6.18 to 6.21 for all of the cases considered in this section will be found in Appendix 3.

- PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- *** MUONS**

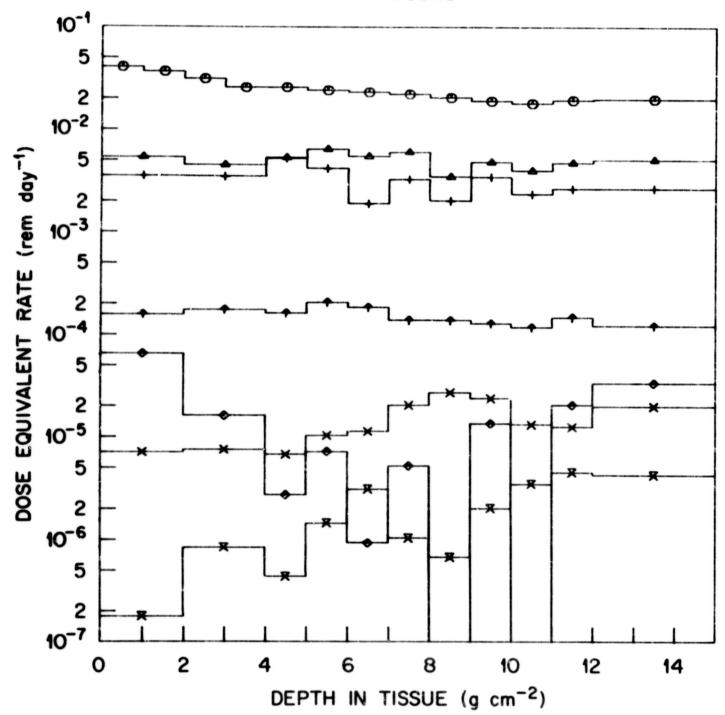


Fig. 6.19. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt proton spectrum corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick aluminum shield (see Fig. 3.1).

- PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- *** MUONS**

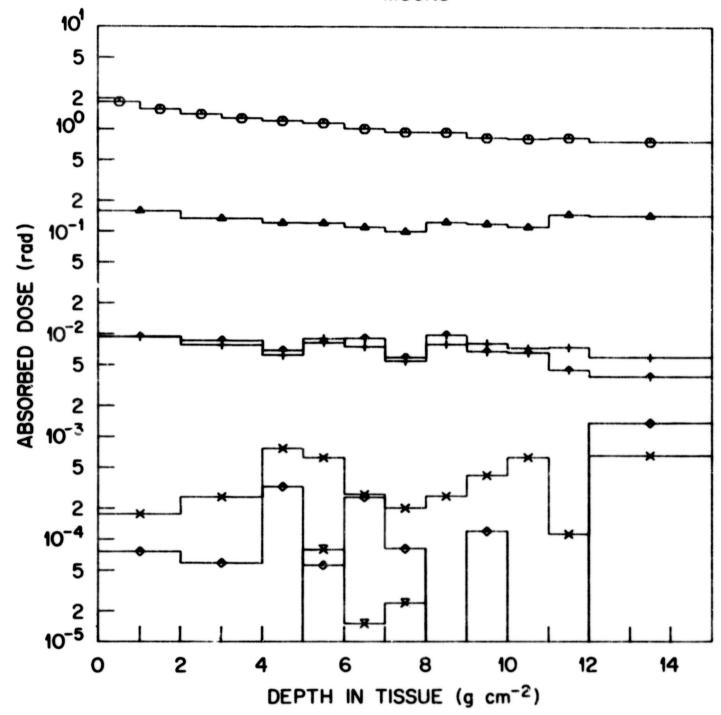


Fig. 6.20. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 20-g-cm⁻²-thick polyethylene shield (see Fig. 3.1).

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- O PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- **×** MUONS

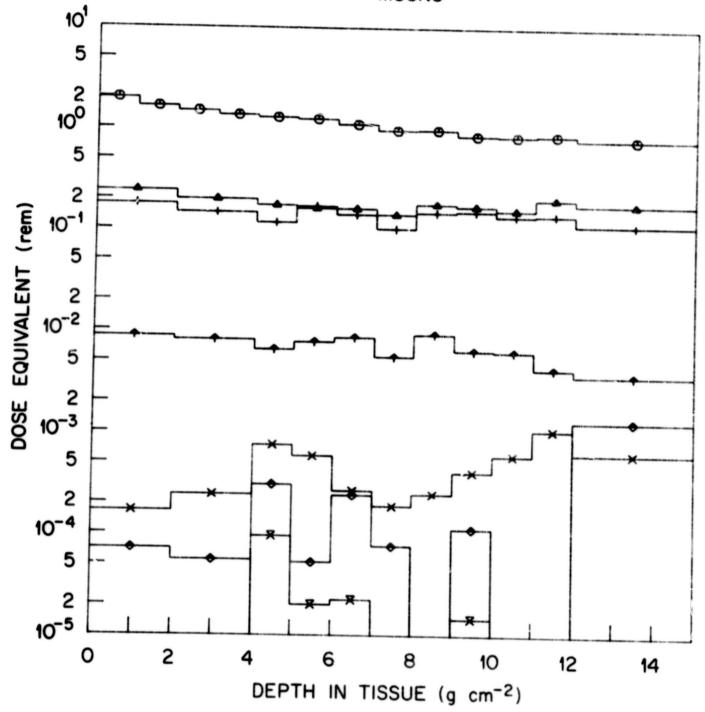


Fig. 6.21. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 20-g-cm⁻²-thick polyethylene shield (see Fig. 3.1).

The total absorbed-dose rate and the total dose-equivalent rate, respectively, i.e., the dose rates with all secondary particles included, are shown in Figs. 6.22 and 6.23 (solid-line histograms) as a function of depth in the tissue sphere for a variety of incident Van Allen belt spectra, shield thicknesses, and shield materials. The total absorbed dose and the total dose equivalent, respectively, are shown in Figs. 6.24 and 6.25 (solid-line histograms) for a variety of incident solar-flare proton spectra, shield thicknesses, and shield materials. Also shown in the figures are the primaryproton dose rates or doses (dashed-line histograms) as a function of depth in the tissue sphere. The primary-proton doses shown in the figures were obtained with the effects of nuclear collisions included; i.e., they correspond to what has previously been termed as the nuclear attenuated primaryproton doses, since the particles produced by these collisions have been explicitly included in the calculations. In order to obtain adequate statistical accuracy in the Monte Carlo calculations, the doses at the center of the tissue sphere have been obtained by averaging over a tissue sphere of 3 cm in radius.

From the space-shielding point of view, the important quantity is the secondary-particle contribution to the dose rates or doses since this is the quantity that must be neglected or drastically approximated in routine space-shielding calculations. This secondary-particle contribution is given by the difference between the corresponding solid- and dashed-line histograms in Figs. 6.22 to 6.25. Within the statistical accuracy attained, the corresponding solid and dashed histograms have a similar shape, so very approximately the secondary-particle contribution to the various doses is independent of the depth in tissue. The secondary-particle contribution is

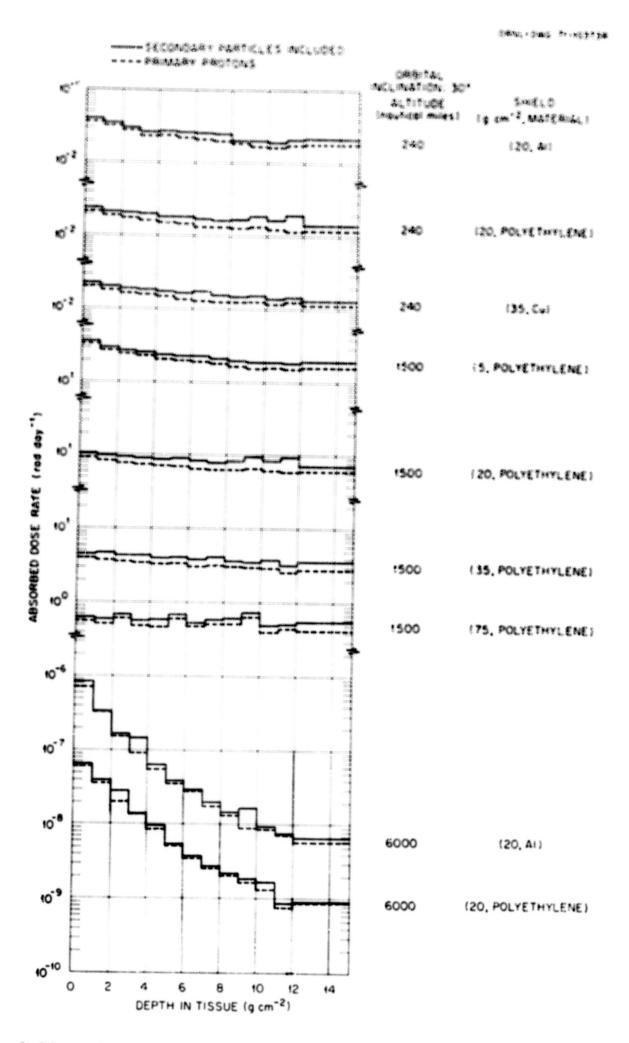


Fig. 6.22. Absorbed-dose rate vs depth in tissue for Van Allen belt proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).



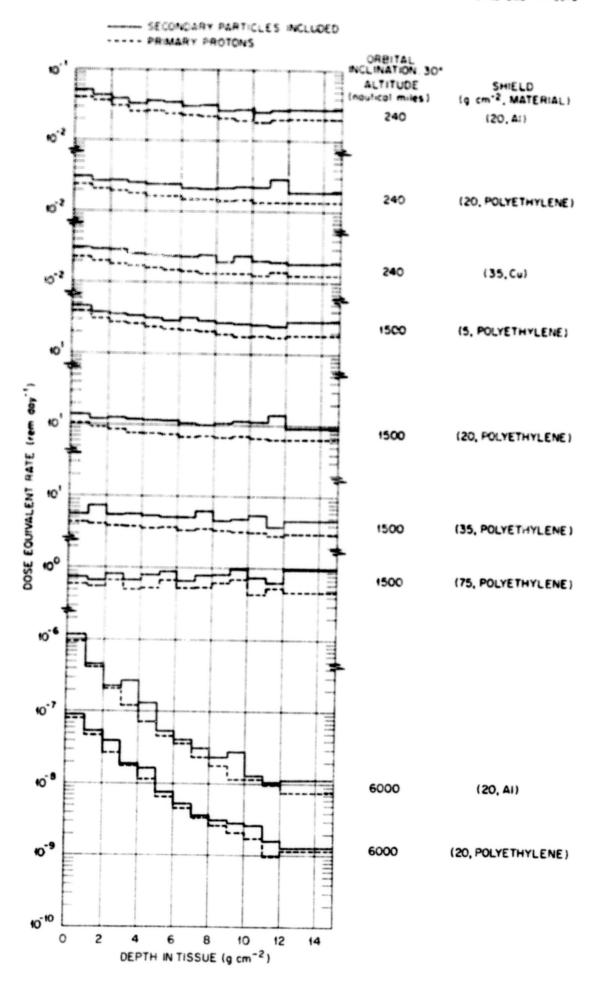


Fig. 6.23. Dose-equivalent rate vs depth in tissue for Van Allen belt proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

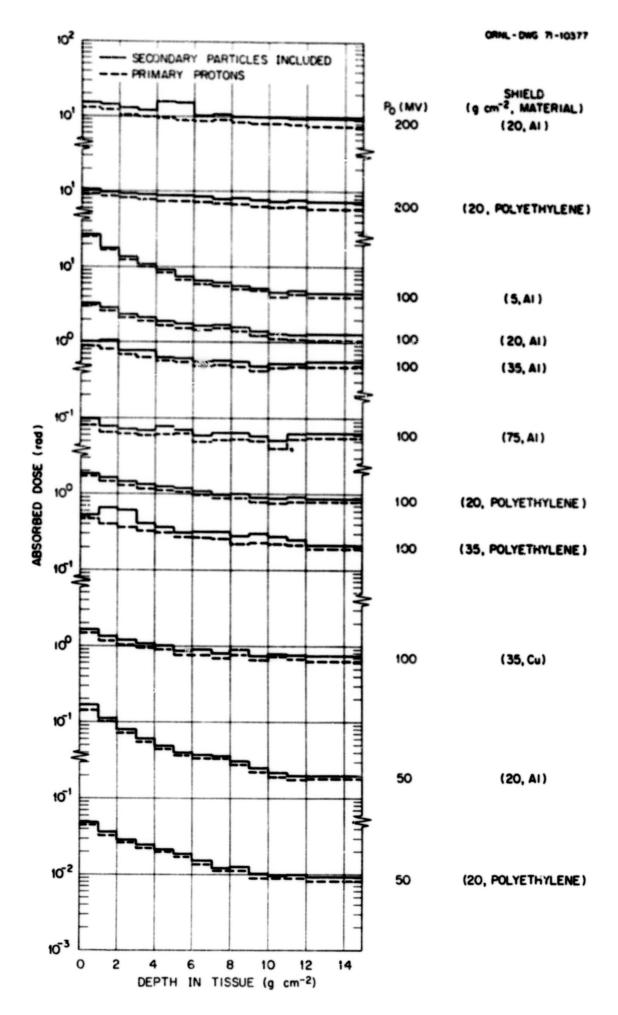


Fig. 6.24. Absorbed dose vs depth in tissue for solar-flare proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

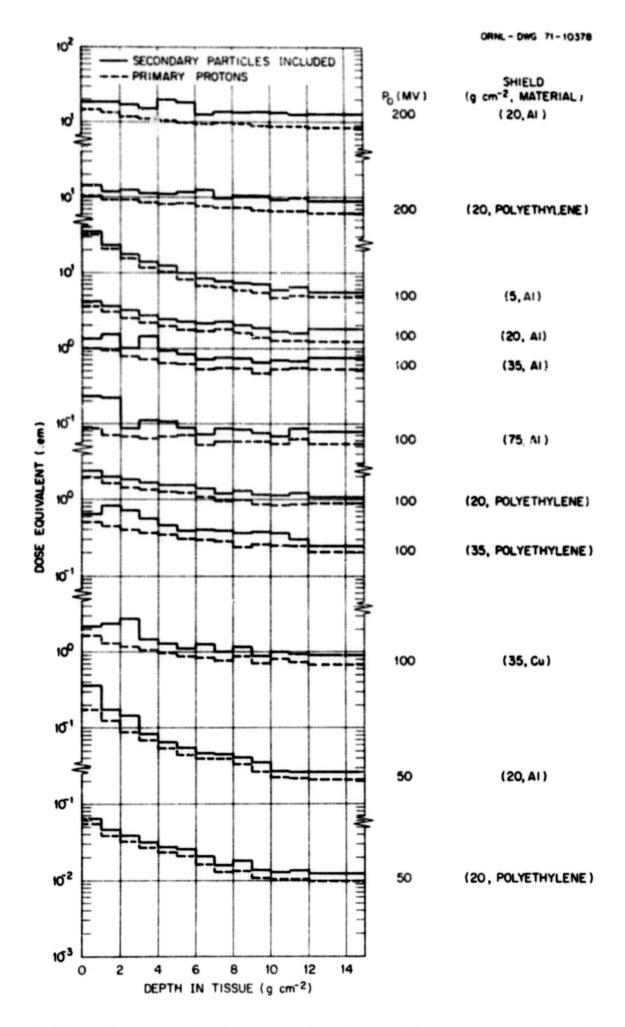


Fig. 6.25. Dose equivalent vs depth in tissue for solar-flare proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

never large, but, as one expects, the secondary particles contribute more to the dose-equivalent rate and dose equivalent than to the absorbed-dose rate and absorbed dose. There is some tendency for the secondary particles to contribute more in the case of a "hard" incident spectrum (upper seven histogram sets in Figs. 6.22 and 6.23 and upper two histogram sets in Figs. 6.24 and 6.25) than in the case of a "soft" incident spectrum (lower two histogram sets in Figs. 6.22 to 6.25). The magnitude of the secondaryparticle contribution is not strongly dependent on shield material. It is interesting to note that the secondary-particle contribution to the various doses is not a strongly varying function of shield thickness (note fourth to seventh histogram sets from the tops of Figs. 6.22 and 6.23 and the third to sixth histogram sets from the tops of Figs. 6.24 and 6,25). Even for a shield thickness of 75 g $\,\mathrm{cm}^{-2}$, the secondary-particle contribution to the various doses is not significantly larger than the primary-particle contribution. This seems to contradict some of the previously published results107 where it was shown that the secondary-particle contribution to the dose equivalent became comparable to the primary-particle contribution for much thinner shields. This apparent contradiction is presumably due to the fact that the geometry considered here is quite different from the geometry used by Irving et al. Irving et al. considered the case of isotropic incidence on a semi-infinite slab shield followed by a 30-cm-thick semi-infinite slab of tissue, while the geometry shown in Fig. 3.1 is used here. Neither geometry is entirely realistic, and therefore the fact that the results are geometry-dependent must be borne in mind.

^{107.} D. C. Irving et al., "The Secondary-Particle Contribution to the Dose from Solar-Flare Protons Incident Isotropically on Slab Shields," Nucl. Sci. Eng. 25, 373 (1966).

The results in Figs. 6.22 to 6.25 are also of interest because they show how the various doses vary as a function of depth in the tissue sphere. It must be remembered that even when only primary particles are considered the dose calculations are relatively simple only if attention is restricted to the center of the tissue sphere. The histograms in Figs. 6.22 to 6.25 indicate that the variation in both the total and primary-proton doses over the 15 g cm⁻² of tissue is strongly dependent on the incident spectrum. For relatively "hard" incident spectra (upper seven histogram sets in Figs. 6.22 and 6.23 and upper two histogram sets in Figs. 6.24 and 6.25), the dose variation over the 15 g cm⁻² of tissue is of the order of a factor of two. For very "soft" incident spectra (lowest two histogram sets in Figs. 6.22 and 6.23), the doses vary by a factor of 100 over the 15 g $\rm cm^{-2}$ of tissue. The magnitude of the dose variation over the tissue depth is smaller for thick shields than for thin shields, as may be seen by comparing the fourth to seventh histogram sets from the tops of Figs. 6.22 and 6.23 and the third to sixth histogram sets from the tops of Figs. 6.24 and 6.25. In general, then, the dose values at the center of the tissue sphere cannot be taken to be representative of the dose values throughout the sphere. The general subject of the dose variation in the tissue sphere is discussed further in Section 6.3.2.

6.3 THE VALIDITY OF USING ONLY PRIMARY PROTONS IN SHIELDING AGAINST INCIDENT PROTON SPECTRA

The results presented in Sections 6.1 and 6.2 are compared in this section in order to obtain estimates of the errors introduced into space-shielding calculations by neglecting or drastically approximating the secondary-particle contribution to the various doses. This is perhaps the most important section in the report since secondary particles in general must be neglected in shielding calculations for actual spacecraft, and it is in this section that this procedure is to some extent justified.

6.3.1 Primary-Proton Transport Without Attenuation from Nuclear Collisions as an Approximate Method for Including the Effects of Secondary Particles

The primary-proton absorbed-dose rate and dose-equivalent rate, respectively, at the center of the tissue sphere are shown in Figs. 6.26 and 6.27 as a function of spherical-shell-shield thickness for a variety of incident Van Allen belt spectra and shield materials. The solid-line curves give the results when the attenuation due to nuclear collisions is neglected and the dashed-line curves give the results when this attenuation is included. Also shown in Figs. 6.26 and 6.27 as plotted points are the absorbed-dose rates and dose-equivalent rates obtained by including secondary-particle production and transport. The plotted points in Figs. 6.26 and 6.27 were obtained by adding the secondary-particle contribution to the dose rates from Figs. 6.22 and 6.23 to the primary-proton dose rates given by TRAPP, i.e., to the dashed curves given in Figs. 6.26 and 6.27. The primary-proton dose rates at the center of the tissue sphere given by TRAPP are, in principle, the same as those given by NMTC, but the TRAPP results are preferable here because they are not subject to the statistical uncertainties inherent

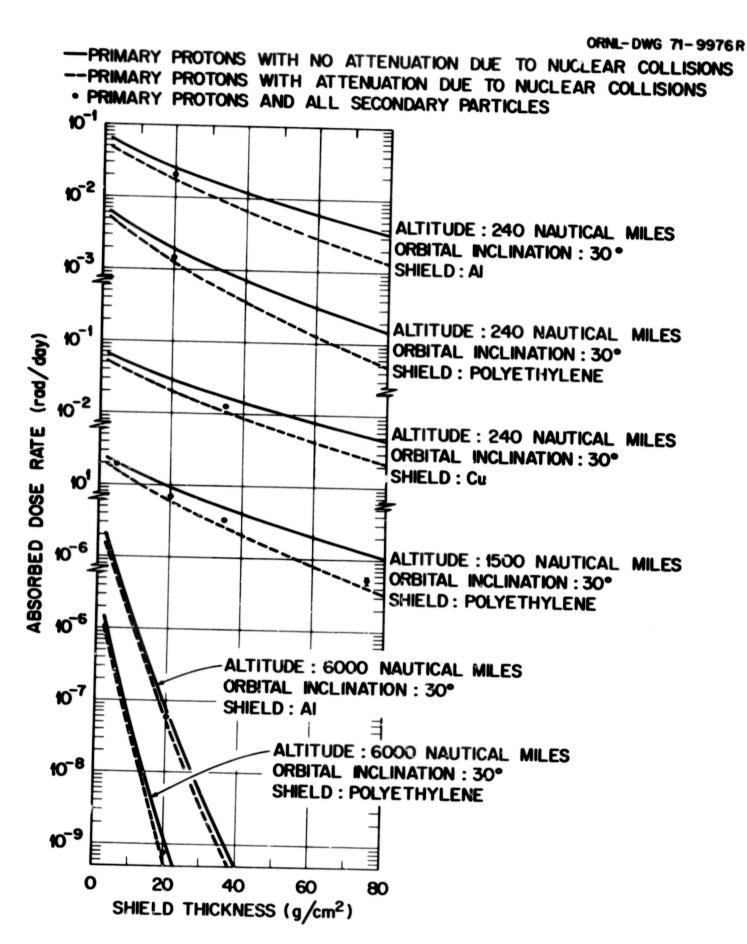


Fig. 6.26. Absorbed-dose rate at the center of the tissue sphere vs shield thickness, r_S , for Van Allen belt spectra isotropically incident on the spherical shell shield (see Fig. 3.1).

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-- PRIMARY PROTONS WITH NO ATTENUATION DUE TO NUCLEAR COLLISIONS

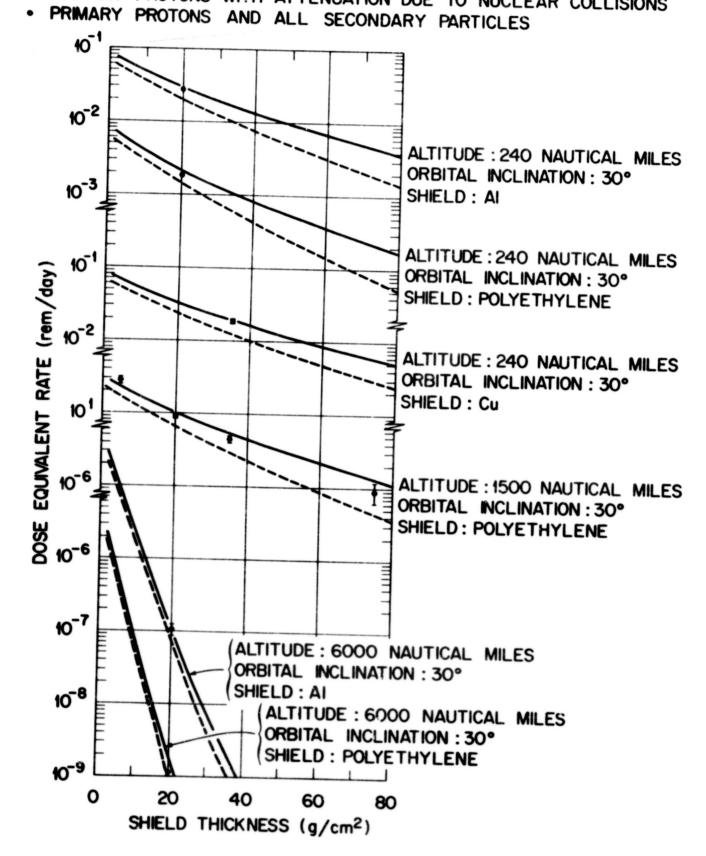


Fig. 6.27. Dose-equivalent rate at the center of the tissue sphere vs shield thickness, $r_{\rm S}$, for Van Allen belt spectra isotropically incident on the spherical shell shield (see Fig. 3.1).

in the NMTC results and because TRAPP gives the dose rates at the geometric center of the tissue sphere whereas NMTC gives the dose rates averaged over a finite region (a 3-cm-radius sphere in Figs. 6.22 and 6.23) around the center of the tissue sphere. The secondary-particle contributions to the dose rates that were used to obtain the values shown by the plotted points in Figs. 6.26 and 6.27 were obtained by averaging over a 3-cm-radius region about the center of the tissue sphere. The error bars on the plotted points in Figs. 6.22 and 6.23 represent one standard deviation in the Monte Carlo calculations of the secondary-particle contributions to the dose rates. When no error bars are shown, the size of the plotted point is larger than error.

The attenuated and unattenuated primary-proton absorbed dose and dose equivalent, respectively, and the total absorbed dose and dose equivalent, respectively are shown in Figs. 6.28 and 6.29 as a function of shield thickness for a variety of incident solar-flare proton spectra and shield materials. The results in Figs. 6.28 and 6.29 were obtained in the same manner as those in Figs. 6.26 and 6.27.

In Fig. 6.26 for all incident spectra and shield materials considered, the total absorbed-dose rate for a given shield thickness is less than the unattenuated primary-proton absorbed-dose rate for the same shield thickness. In Fig. 6.27 for almost all incident spectra and shield materials considered, the total dose-equivalent rate for a given shield thickness is less than the unattenuated primary-proton dose-equivalent rate for the same shield thickness. The exception in Fig. 6.27 is for a Van Allen belt spectrum, corresponding to an altitude of 1500 nautical miles, incident on a 5-g-cm⁻²-thick polyethylene shield. In this case, the total dose-equivalent

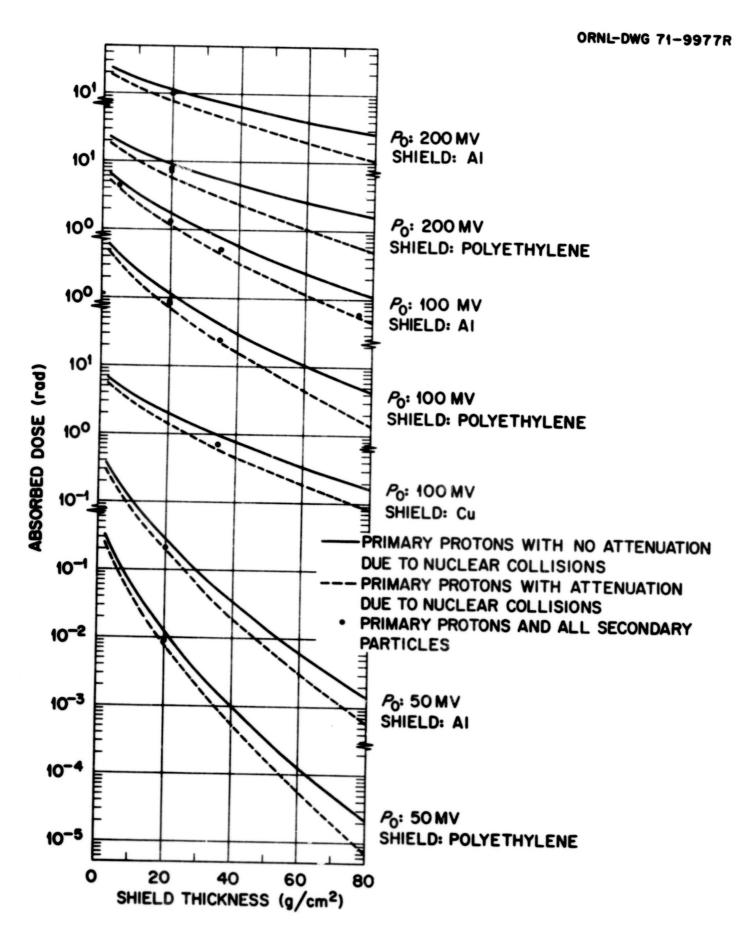


Fig. 6.28. Absorbed dose at the center of the tissue sphere vs shield thickness, r_S, for solar-flare proton spectra isotropically incident on the spherical shell shield (see Fig. 3.1).

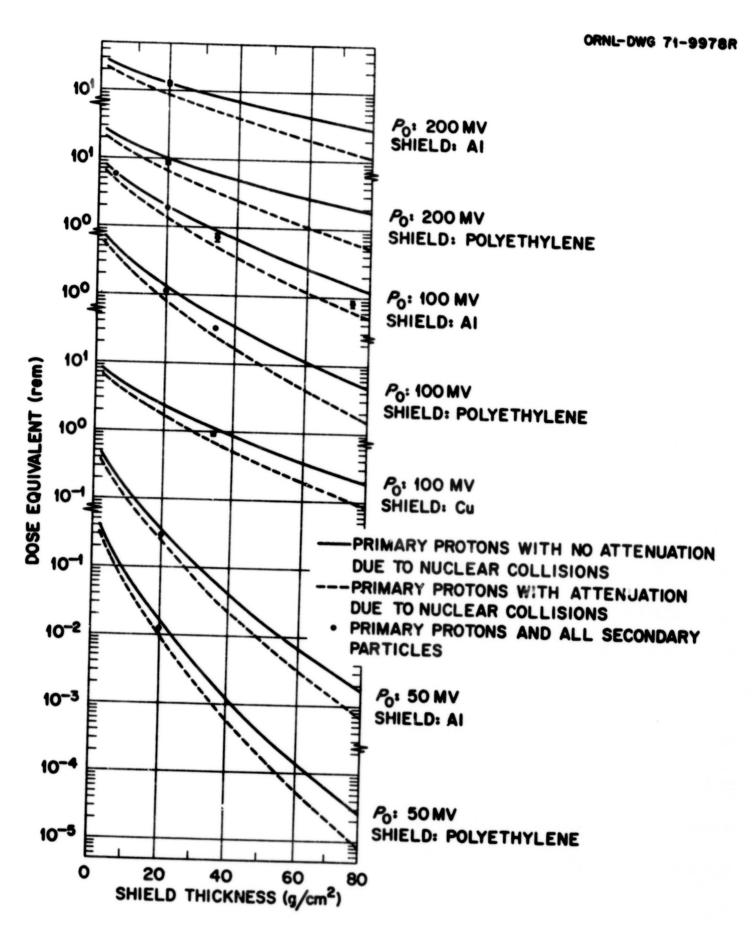


Fig. 6.29. Dose equivalent at the center of the tissue sphere vs shield thickness, r_S , for solar-flare proton spectra isotropically incident on the spherical shell shield (see Fig. 3.1).

rate is slightly larger than the unattenuated primary-proton dose-equivalent rate. The results in Figs. 6.28 and 6.29 are similar to those in Figs. 6.26 and 6.27; i.e., the unattenuated primary-proton absorbed dose for a given shield thickness is greater than the total absorbed dose for the same shield thickness, and, similarly, for the dose equivalent.

For the wide range of incident spectra, shield thicknesses, and shield materials considered in Figs. 6.26 to 6.29 and for the specific geometry considered, a conservative estimate of the various doses is obtained by considering unattenuated primary protons only. It is interesting to note that this is true in the particular geometry considered here, even for shield thicknesses of 75 g $\,\mathrm{cm}^{-2}$. The overestimate to the absorbed-dose rate in Fig. 6.26 and the absorbed dose in Fig. 6.28, obtained by considering unattenuated primary protons only, is in general larger than the overestimate to the dose-equivalent rate in Fig. 6.27 and the dose equivalent in Fig. 6.29, obtained by considering unattenuated primary protons only. On the basis of the results shown in Figs. 6.26 to 6.29, it seems clear that in space-shielding calculations when secondary particles are not considered and when Van Allen belt and solar-flare protons are incident on the shield, the unattenuated primary-proton flux per unit energy should be used to obtain dose estimates since, for radiation-protection purposes, it is preferable to obtain an overestimate rather than an underestimate of the dose or dose rate. It must be emphasized, however, that there is no theoretical reason why the total absorbed-dose rate or absorbed dose and the total dose-equivalent rate or dose equivalent cannot be larger than the estimates of these quantities obtained using the unattenuated primary-proton flux per unit energy, and there fore the results in Figs. 6.26 to 6.29 cannot be taken as "proof" that dose estimates obtained with unattenuated primary protons will always be conservative.

6.3.2 A Method for Estimating the Dose Variation Over a Tissue Sphere at the Center of a Spherical Shell Shield

Even if unattenuated primary protons only are considered, the dose calculations are relatively simple only if attention is restricted to the center of the tissue sphere. On the other hand, the results in Figs. 6.22 to 6.25 indicate that for some incident spectra there is a large variation between the doses at the surface of the tissue sphere and the doses at the center of the sphere. Much of this variation is due to the presence of the tissue, and therefore the question arises as to whether the dose at the center of a spherical shell shield with the tissue sphere radius set equal to zero is a reliable estimate of the dose at the surface of the tissue sphere.

In Table 6.1 the attenuated and unattenuated absorbed-dose rates and dose-equivalent rates at the center of various shell-shield thicknesses (with $r_{\rm T}$ = 0) and for various incident Van Allen belt spectra are compared with the total absorbed-dose rate and dose-equivalent rate at the surface of the tissue sphere. The total dose rates at the surface of the tissue sphere, i.e., the dose rates when secondary particles are included, were obtained by averaging over a 1-cm radial interval, as shown in Figs. 6.22 and 6.23. The errors in the total dose rates represent one standard deviation in the Monte Carlo calculations. In Table 6.2 similar comparisons are shown for the absorbed dose and dose equivalent from incident solar-flare proton spectra.

For all cases considered in Table 6.2, the unattenuated and attenuated primary-proton absorbed-dose rates at the center of the shield are larger than the total absorbed-dose rate at the surface of the tissue sphere, and the unattenuated and attenuated primary-proton dose-equivalent rates at the center of the shield are larger than the total dose-equivalent rate at the

Comparison of the Primary Proton Absorbed-Dose Rate and Dose-Equivalent Rate at the Center of a Spherical Shell Shield with the Total Absorbed-Dose Rate and Dose-Equivalent Rate at the Surface of the Tissue Sphere (see Fig. 3.1) for Various Incident Van Allen Belt Spectra

					(rad day ⁻¹)	te	Dose-Equivalent Rate			
Altitude (nautical miles)	Orbital Inclination (deg)	Snield Material	Shield Thickness (g cm ⁻²)	Primary Protons Without Attenuation (r _T = 0)	Primary Protons With Attenuation (r _T = 0)	Total at Surface of Tissue Sphere (r _T = 15 g cm ⁻²)	Primary Protons Without Attenuation (r _T = 0)	(rem day ⁻¹) Primary Protons With Attenuation	Total at Surface of Tissue Sphere	
240	30	Aluminum	20	7.07 × 10 ⁻²	5.79 × 10 ⁻²	3.96 × 10 ⁻²	8.46 × 10 ⁻²	(r _T = 0)	(r _T = 15 g cm ⁻²)	
240	30	Polyethylene	20	4.53 × 10 ⁻²	3.50 × 10 ⁻²	\pm 1.46 × 10 ⁻³		6.92 × 10 ⁻²	5.15×10^{-2} ± 2.93 × 10 ⁻³	
240	30	Copper	35	4.15 × 10 ⁻²		2.39 × 10 ⁻² ± 1.84 × 10 ⁻³	5.18 × 10 ⁻²	3.98 × 10 ⁻²	3.08×10^{-2} ± 2.46×10^{-3}	
1500	30	Polyethylene	5		3.21 × 10 ⁻²	2.23 × 10 ⁻² ± 7.80 × 10 ⁻⁴	5.02 × 10 ⁻²	3.88 × 10 ⁻²	3.07 × 10 ⁻² ± 2.08 × 10 ⁻³	
1500	30			5.97 × 10 ¹	5.53 × 10 ¹	3.58×10^{1} ± 9.31×10^{-1}	7.06 × 10 ¹	6.53 × 10 ¹	4.65 × 10 ¹ ± 1.18 × 10 ⁰	
		Polyethylene	20	1.86×10^{1}	1.44 × 10 ¹	1.05 × 10 ¹ ± 7.98 × 10 ⁻¹	2.10 × 10 ¹	1.62 × 10 ¹	1.37 × 10 ¹	
1500	30	Polyethylene	35	8.75 × 10 ⁰	5.70 × 10 ⁰	4.60 × 10 ⁰	9./1 × 10 ⁰	6.31 × 10 ⁰	± 1.08 × 10 ⁻¹	
1500	30	Polyethylene	75	1.90 × 100	7.80 × 10 ⁻¹	$\pm 2.02 \times 10^{-1}$ 6.30×10^{-1}	2.10 100		5.62 × 10 ⁰ ± 2.47 × 10 ⁻¹	
6000	30	Aluminum	20	3.48 × 10 ⁻⁶		\pm 6.11 × 10 ⁻²	2.10 × 10 ⁰	8.40 × 10 ⁻¹	7.34×10^{-1} ± 7.34×10^{-2}	
6000	30	Palmashu1			2.82 × 10 ⁻⁶	8.36 × 10 ⁻⁷ ± 1.04 × 10 ⁻⁷	5.37 × 10 ⁻⁶	4.35 × 10 ⁻⁶	1.18 × 10 ⁻⁶ ± 1.51 × 10 ⁻⁷	
		Polyethylene	20	2.63 × 10 ⁻⁷	1.99 × 10 ⁻⁷	6.55 × 10 ⁻⁸ ± 3.99 × 10 ⁻⁹	3.72 × 10 ⁻⁷	2.81 × 10 ⁻⁷	9.03 × 10 ⁻⁷ ± 6.41 × 10 ⁻⁹	

TABLE 6.2

Comparison of the Primary Proton Absorbed Dose and Dose Equivalent at the Center of a Spherical Shell Shield with the Total Absorbed Dose and Dose Equivalent at the Surface of the Tissue Sphere (see Fig. 3.1) for Various Incident Solar-Flare Proton Spectra

				Absorbed D (rad)	ose	Dose Equivalent (rem)			
Characteristic Rigidity (MV)	Shield Material	Shield Thickness (g cm ⁻²)	Primary Protons Without Attenuation (r _T = 0)	Primary Protons With Attenuation (r _T = 0)	Total at Surface of Tissue Sphere (r _T = 15 g cm ⁻²)	Primary Protons Without Attenuation (r _T = 0)	Primary Protons With Attenuation (r _T = 0)	Total at Surface of Tissue Sphere (r _T = 15 g cm ⁻²)	
200	Aluminum	20	2.58 × 10 ¹	2.12 × 10 ¹	1.51×10^{1} ± 1.40×10^{0}	3.03 × 10 ¹	2.48 × 10 ¹	1.87 × 10 ¹ ± 1.70 × 10 ⁰	
200	Polyethylene	20	1.77 × 10 ¹	1.37 × 10 ¹	1.08 × 10 ¹ ± 4.97 × 10 ⁻¹	1.99 × 10 ¹	1.54 × 10 ¹	1.43 × 10 ¹ ± 9.44 × 10 ⁻¹	
100	Aluminum	5	7.11 × 10 ¹	6.71 × 10 ¹	2.68 × 10 ¹ ± 1.47 × 10 ⁰	1.02 × 10 ²	9.61 × 10 ¹	3.55 × 10 ¹ ± 2.38 × 10 ⁰	
100	Aluminum	20	7.58 × 10 ⁰	6.19 × 10 ⁰	3.30 × 10 ⁰ ± 1.45 × 10 ⁻¹	9.50 × 10 ⁰	7.75 × 10 ⁰	4.24 × 10 ⁰ ± 2.58 × 10 ⁻¹	
100	Aluminum	35	2.28 × 10 ⁰	1.63 × 10 ⁰	1.02 × 10 ⁰ ± 7.45 × 10 ⁻²	2.76 × 10 ⁰	1.97 × 10 ⁰	1.35 × 10 ⁰ ± 1.30 × 10 ⁻¹	
100	Aluminum	75	2.88 × 10 ⁻¹	1.42 × 10 ⁻¹	9.73 × 10 ⁻² ± 7.88 × 10 ⁻³	3.22 × 10 ⁻¹	1.65 × 10 ⁻¹	2.35 × 10 ⁻¹ ± 1.14 × 10 ⁻¹	
100	Polyethylene	20	3.87 × 10 ⁰	2.97 × 10 ⁰	1.86 × 10 ⁰ ± 7.44 × 10 ⁻²	4.57 × 10 ⁰	3.50 × 10 ⁰	2.42 × 10 ⁰ ± 1.36 × 10 ⁻¹	
. 100	Polyethylene	35	1.03 × 10 ⁰	6.68 × 10 ⁻¹	4.87 × 10 ⁻¹ ± 3.11 × 10 ⁻²	1.18 × 10 ⁰	7.64 × 10 ⁻¹	6.74 × 10 ⁻¹ ± 8.29 × 10 ⁻²	
100	Copper	35	3.36 × 10 ⁰	2.59 × 10 ⁰	1.61×10^{0} ± 6.28×10^{-2}	4.24 × 10 ⁰	3.26 × 10 ⁰	2.14 × 10 ⁰ ± 9.63 × 10 ⁻²	
50	Aluminum	20	4.73 × 10 ⁻¹	3.85 × 10 ⁻¹	1.67 × 10 ⁻¹ ± 2.30 × 10 ⁻²	6.46 × 10 ⁻¹	5.25 × 10 ⁻¹	3.60 × 10 ⁻¹ ± 1.75 × 10 ⁻¹	
50	Polyethylene	20	1.35 × 10 ⁻¹	1.03 × 10 ⁻¹	4.81×10^{-2} $\pm 2.50 \times 10^{-3}$	1.71 × 10 ⁻¹	1.30 × 10 ⁻¹	6.55×10^{-2} ± 4.19×10^{-3}	

surface of the tissue sphere. For the cases considered in Table 6.2, the results are similar to those in Table 6.1, except in one case, $P_o = 100 \text{ MV}$ on 75 g cm $^{-2}$ of aluminum, the attenuated primary-proton dose equivalent is less than the total dose equivalent. Thus for all of the cases considered, an upper limit on the total dose rates or doses at the surface of the tissue sphere is given by the unattenuated primary-proton dose rates or doses at the center of the shield with the tissue sphere absent. For almost all cases tested, a more nearly correct estimate, but still an upper bound, is given by the attenuated primary-proton dose rate or dose. It must be emphasized that the results in the tables are for a very special geometry and may be very geometry-dependent.

Dose values obtained with TRAPP for a large variety of incident Van Allen belt and solar-flare spectra are presented in Appendix 2. For each spectrum considered, data obtained with attenuated and unattenuated primary particles and with $r_T=0$ and $r_T=15~{\rm g~cm}^{-2}$ are given.

6.4 SHIELDING AGAINST INCIDENT ALPHA PARTICLES

Because of the lack of information concerning particle production from high-energy alpha-particle-nucleus collisions, shielding calculations for incident alpha particles that include secondary-particle production and transport are not available. Therefore, it is not possible to estimate the error involved in utilizing the unattenuated primary-alpha-particle flux per unit energy to obtain dose estimates. However, lacking other information, this would seem to be the most reasonable approximation to make.

There is also no specific information on the magnitude of the variation of the dose in the tissue sphere (Fig. 3.1) in the case of incident alpha particles, but when only primary particles are considered, some information on this variation is given in Section 6.7.

Absorbed-dose and dose-equivalent values obtained using primary particles only for a variety of incident solar-flare alpha-particle spectra are given in Appendix 2. For each spectrum considered, the doses at the center of the shield obtained with both attenuated and unattenuated primary particles and with $r_T = 15 \ g \ cm^{-2}$ and $r_T = 0$ are given.

6.5 THE VALIDITY OF THE EQUIVALENT-THICKNESS APPROXIMATION

An equivalent-thickness approximation was described in Section 3.5 and some information on the parameters that occur in the approximation was given in Section 4.3. In this section, the validity of the approximation is examined by comparing calculated dose results obtained with the approximation with calculated dose results obtained without the approximation.

All of the calculated data presented in this section will be for the geometry shown in Fig. 3.1 with $\rm r_T=15~g~cm^{-2}$. All of the dose values given are for the center of the tissue sphere and were obtained using the unattenuated primary-particle flux or fluence per unit energy. The incident particle flux or fluence per unit energy in all cases is that described in Sections 2.1.5 and 2.2.2. The standard material in the equivalent-thickness approximation was taken to be aluminum, and in general for all materials (see Section 4.3)

$$K_{A,A\ell,p} = \left[\frac{S_{Ap}(E)}{S_{A\ell p}(E)}\right]_{E = 50 \text{ MeV}}$$

$$K_{A,Al,\alpha} = \left[\frac{S_{A\alpha}(E)}{S_{Al\alpha}(E)}\right]_{E = 150 \text{ MeV}}$$

At the end of this section some data for other choices of K_{A,Al,j} are given for comparative purposes. Essentially all of the calculated results presented in this section were obtained with TRAPP. In the case of the equivalent-thickness approximation, the doses were obtained by interpolating in the TRAPP results for aluminum that are given in Appendix 2.

The absorbed-dose rate and dose-equivalent rate, respectively, at the center of the tissue sphere are shown in Figs. 6.30 and 6.31 as a function of shield thickness for several incident Van Allen belt spectra and for several shield materials. The solid-line curves, labeled "TRAPP," show the dose rates when the stopping powers in Figs. 4.1 and 4.3 are used. plotted points show the dose rates obtained in the equivalent-thickness approximation. For the thinner shields (\leq 30 g cm⁻²), the plotted points and solid curves are in excellent agreement in all cases in both Figs. 6.30 and 6.31. In the case of aluminum, the approximation gives a very good estimate of the dose rates for all shield thicknesses and for all incident spectra considered in Figs. 6.30 and 6.31. In the case of an aluminum shield, since aluminum is used as the standard material, the equivalent-thickness approximation is inexact only for the tissue, and therefore it is to be expected that the approximation is more valid in this case than in the case of other shield materials. In the case of polyethylene and copper shields, there are slight differences between the plotted points and solid curves at the larger thicknesses. These differences are most apparent in the case of very soft spectra (the lower two curves in Figs. 6.30 and 6.31).

The absorbed dose and dose equivalent, respectively, at the center of the tissue sphere are shown in Figs. 6.32 and 6.33 as a function of shield thickness for several incident solar-flare proton spectra and for several

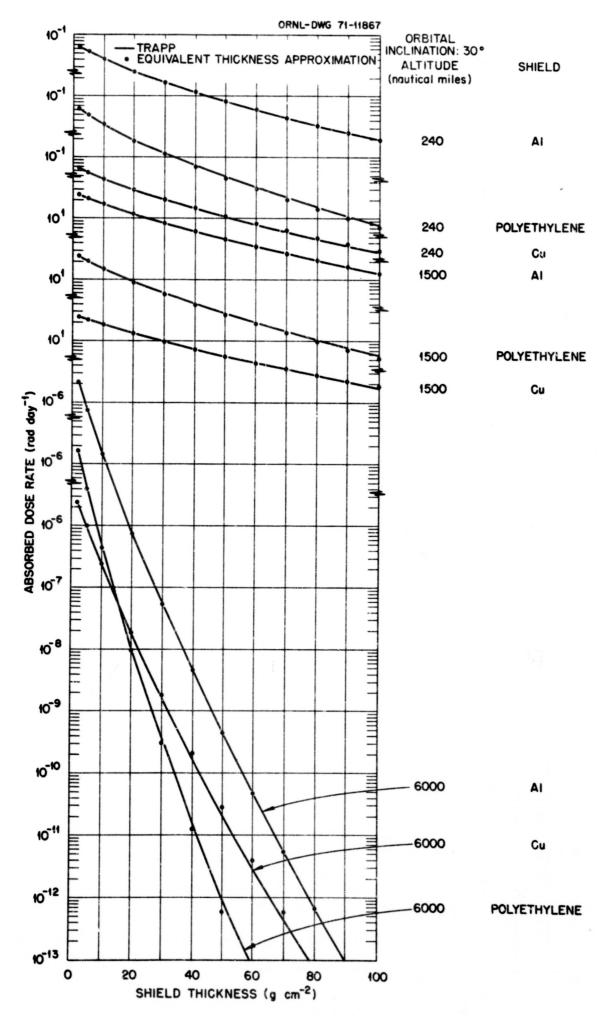


Fig. 6.30. Absorbed-dose rate from unattenuated primary protons at the center of the tissue sphere vs spherical-shell-shield thickness for various incident Van Allen belt spectra.

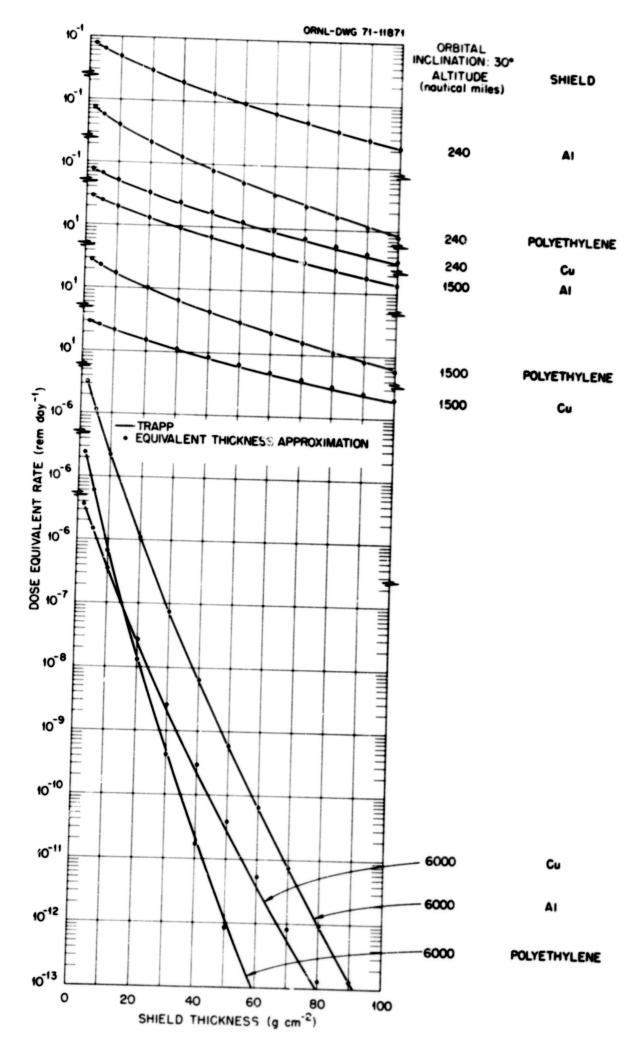


Fig. 6.31. Dose-equivalent rate from unattenuated primary protons at the center of the tissue sphere vs spherical-shell-shield thickness for various incident Van Allen belt spectra.

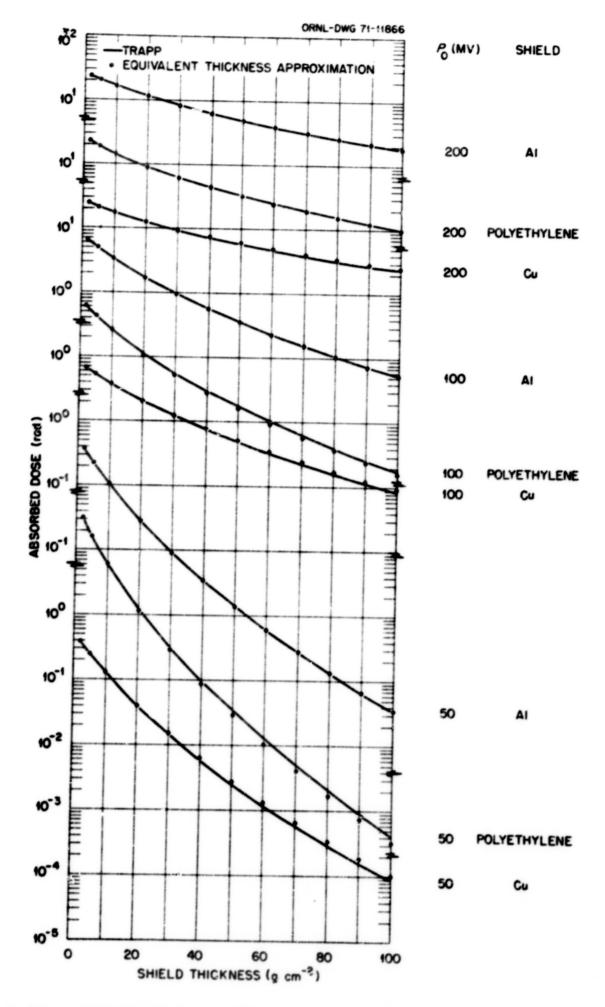


Fig. 6.32. Absorbed dose from unattenuated primary protons at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare proton spectra.

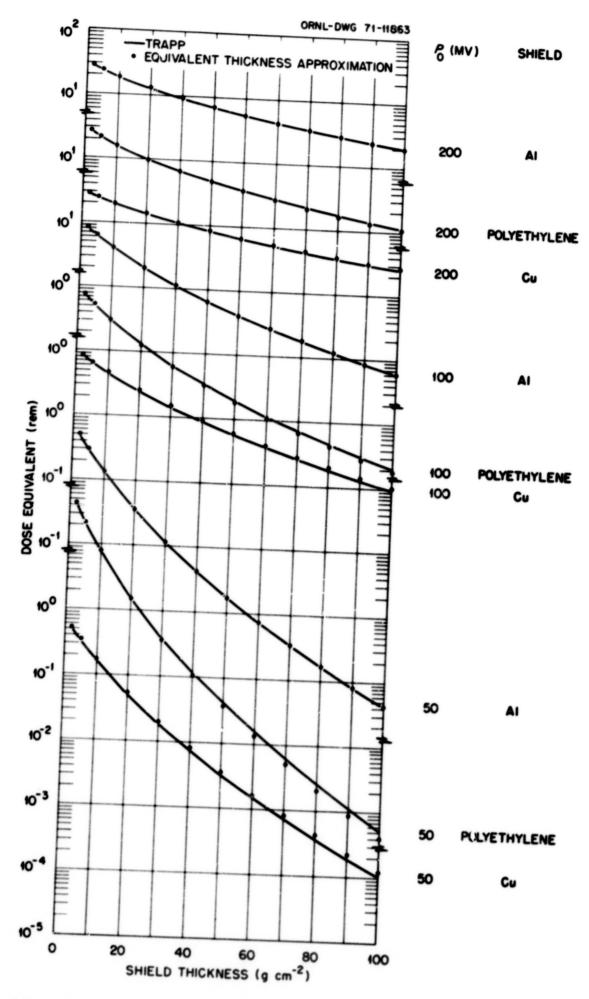


Fig. 5.33. Dose equivalent from unattenuated primary protons at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare proton spectra.

shield materials. The comparisons in Figs. 6.32 and 6.33 are quite similar to those in Figs. 6.30 and 6.31.

The absorbed dose and dose equivalent, respectively, at the center of the tissue sphere are shown in Figs. 6.34 and 6.35 as a function of shield thickness for several incident solar-flare alpha-particle spectra and several shield materials. The errors introduced by using the equivalent-thickness approximation for alpha particles are slightly larger at the larger shield thicknesses than those introduced by using the approximation for protons.

The comparisons shown in Figs. 6.30 to 6.35 are based on a particular choice of the energy at which the stopping-power ratios are evaluated to find the constants $K_{A,A\ell,j}$ that occur in the equivalent-thickness approximation. These comparisons are not, however, strongly dependent on the choice of this energy. To show this, the dose values for shield thicknesses of 2 and 100 g cm⁻² are given in Tables 6.3 to 6.5 for several different values of $K_{A,A\ell,j}$. The incident spectra and shield materials considered in the tables are the same as those considered in the figures. The values given in the columns labeled "TRAPP" are the same as those shown by the corresponding solid curves in Figs. 6.30 to 6.35. Similarly, the values given in Tables 6.3 and 6.4 when the stopping-power ratios are evaluated at E = 50 MeV correspond to the plotted points in Figs. 6.30 to 6.33, and the values given in Table 6.5 when the stopping-power ratios are evaluated at 150 MeV correspond to the plotted points in Figs. 6.34 and 6.35.

In general, the equivalent-thickness approximation gives good results for both protons and alpha particles and can be used, therefore, to substantially reduce the computational effort required to carry out spaceshielding calculations based on unattenuated primary particles only.

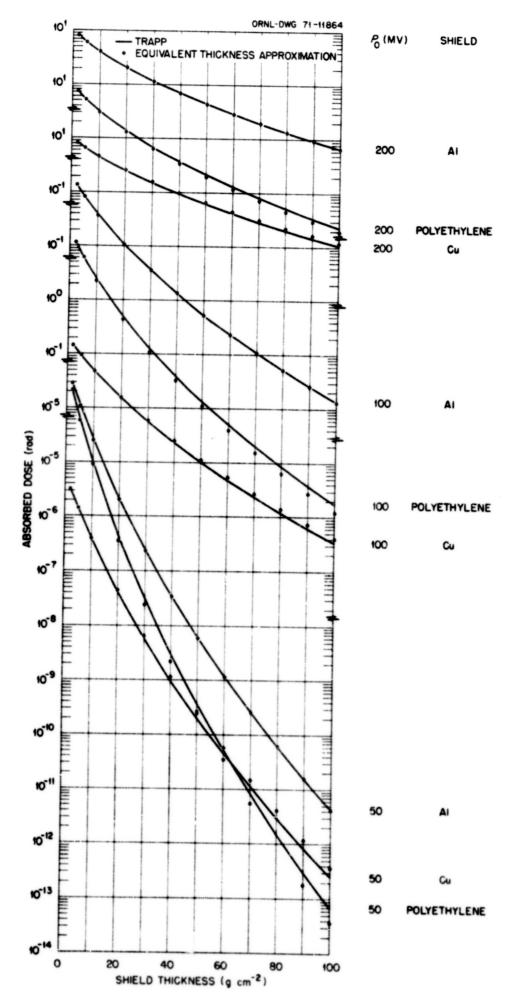


Fig. 6.34. Absorbed dose from unattenuated primary alpha particles at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare alpha-particle spectra.

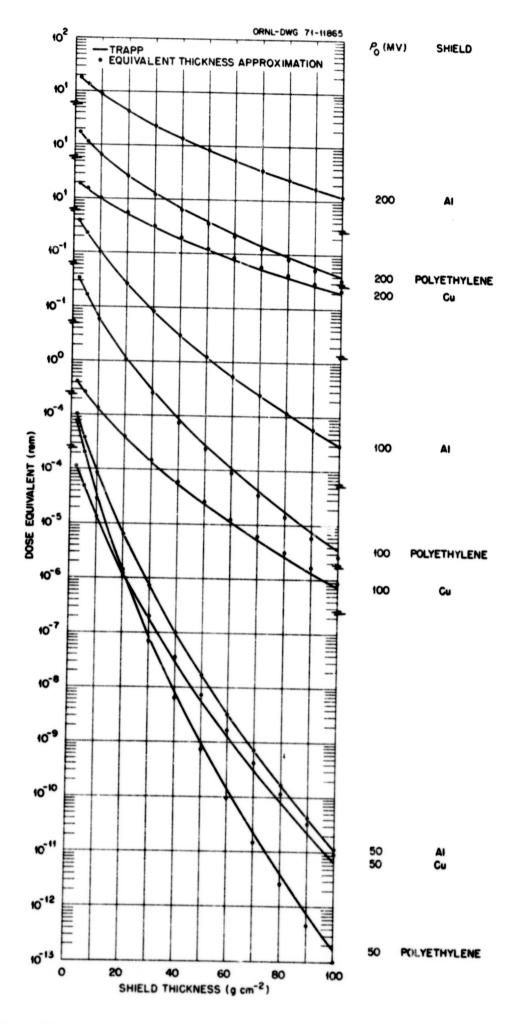


Fig. 6.35. Dose equivalent from unattenuated primary alpha particles at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare alpha-particle spectra.

TABLE 6.3

Sensitivity of Dose-Rate Results Obtained with the Equivalent-Thickness Approximation to the choice of $K_{A,A\ell,p}$ for Incident Van Allen Belt Spectra

				Unattenuated Primary Proton Absorbed-Dose Rate (r _T = 15 g cm ⁻²) (rad day ⁻¹)				Unattenuated Primary Proton Dose-Equivalent Rate			
miles)	Orbital Inclination (deg)	Shield Material	Shield Thickness (g cm ⁻²)	TRAPP	(A,A£,p) $\left[\frac{S_{Ap}}{S_{A2p}}\right]_{E=25 \text{ MeV}}$	$K_{A,A2,p}$ $= \left[\frac{S_{Ap}}{S_{A2p}}\right]_{E=50 \text{ MeV}}$	$K_{A,AR,p}$ $= \left[\frac{S_{Ap}}{S_{ARp}}\right]_{E=75 \text{ MeV}}$		KA,A£,p	KA,A£,p	$K_{A,A\ell,p}$ $= \left[\frac{S_{Ap}}{S_{A\ell p}}\right]_{E=75 \text{ Me}}$
240 240	30 30	Aluminum Aluminum	2 100	6.45×10^{-2} 1.92×10^{-3}	6.39 × 10 ⁻² 1.92 × 10 ⁻³	6.50 × 10 ⁻² 1.93 × 10 ⁻³	6.55 × 10 ⁻²	7.48 × 10 ⁻²	7.62 × 10 ⁻²	7.75 × 10 ⁻²	7.82 × 10 ⁻²
240 240	30 30	Polyethylene Polyethylene		6.13 × 10 ⁻² 7.91 × 10 ⁻⁴	6.08 × 10 ⁻² 6.70 × 10 ⁻⁴	6.21 × 10 ⁻² 7.19 × 10 ⁻⁴	1.94×10^{-3} 6.26×10^{-2}	2.11×10^{-3} 7.15×10^{-2}	2.16×10^{-3} 7.24×10^{-2}	2.17×10^{-3} 7.39×10^{-2}	2.18 × 10 ⁻³ 7.46 × 10 ⁻²
240 240	30 30	Copper Copper	2 100	6.56 × 10 ⁻² 2.77 × 10 ⁻³	6.52 × 10 ⁻² 3.08 × 10 ⁻³	6.63 × 10 ⁻²	7.43×10^{-4} 6.67×10^{-2}	8.68×10^{-4} 7.62×10^{-2}	7.49×10^{-4} 7.78×10^{-2}	8.04 × 10 ⁻⁴ 7.91 × 10 ⁻²	8.31 × 10 ⁻⁴ 7.97 × 10 ⁻²
1500 1500	30 30	Aluminum Aluminum	2 100	2.48 × 10 ¹ 1.27 × 10 ⁰	2.46×10^{1}	2.98×10^{-3} 2.50×10^{1}	2.93×10^{-3} 2.51×10^{1}	3.07 × 10 ⁻³ 2.82 × 10 ¹	3.48×10^{-3} 2.88×10^{1}	3.36×10^{-3} 2.92×10^{1}	3.30×10^{-3}
1500 1500	30 30	Polyethylene Polyethylene	2	2.39 × 10 ¹ 5.87 × 10 ⁻¹	1.27×10^{0} 2.37×10^{1}	1.28×10^{0} 2.40×10^{1}		1.39×10^{0} 2.72×10^{1}	1.42×10^{0} 2.76×10^{1}	1.43×10^{0}	2.94×10^{1} 1.43×10^{0}
1500 1500	30 30	Copper	2	2.51×10^{1}	5.08×10^{-1} 2.50×10^{1}	5.40×10^{-1} 2.53×10^{1}	5.55 × 10 ⁻¹	6.39×10^{-1} 2.86×10^{1}	5.63×10^{-1}		2.83×10^{1} 6.16×10^{-1}
6000	30	Copper Aluminum	100	1.75×10^{0} 2.16×10^{-6}	1.92 × 10 ⁰ 1.92 × 10 ⁻⁶	1.87×10^{0} 2.13×10^{-6}	1.84 × 10 ⁰	1.93×10^{0}	2.93×10^{1} 2.15×10^{0}		2.98×10^{1} 2.06×10^{0}
6000	30	Aluminum	100	1.32 × 10 ⁻¹⁶	1.24 × 10 ⁻¹⁶	1.31 × 10 ⁻¹⁶		3.14 × 10 ⁻⁶ 1.74 × 10 ⁻¹⁶	2.95×10^{-6} 1.72×10^{-16}	3.27 × 10 ⁻⁶	3.43×10^{-6}
6000 6000		Polyethylene Polyethylene	100	1.68×10^{-6} 2.13×10^{-19}	1.44 × 10 ⁻⁶ 5.71 × 10 ⁻²⁰	1.62×10^{-6} 9.62×10^{-20}	1.71 × 10 ⁻⁶	2.43 × 10 ⁻⁶ 2.79 × 10 ⁻¹⁹	2.19×10^{-6}	2.48×10^{-6}	1.87×10^{-16} 2.62×10^{-6}
6000 6000		Copper Copper	2 100	2.39 × 10 ⁻⁶ 1.79 × 10 ⁻¹⁵	2.17 × 10 ⁻⁶ 3.66 × 10 ⁻¹⁵	2.38 × 10 ⁻⁶ 2.86 × 10 ⁻¹⁵	2.49 × 10 ⁻⁶	3.48 × 10 ⁻⁶ 2.38 × 10 ⁻¹⁵	7.81 × 10 ⁻²⁰ 3.34 × 10 ⁻⁶ 5.09 × 10 ⁻¹⁵		1.68 × 10 ⁻¹⁹ 3.82 × 10 ⁻⁶

TABLE 6.4

Sensitivity of Dose Results Obtained with the Equivalent-Thickness Approximation to the Choice of K_{A,Al,p} for Incident Solar-Flare Proton Spectra

			Una	r _T = 15 (r _T = 15)	g cm ⁻²)	d Dose	Unattenuated Primary Proton Dose Equivalent $(r_T = 15 \text{ g cm}^{-2})$ (rem)				
Character- istic Rigidity (MV)	Shield Material	Shield Thickness (g cm ⁻²)	TRAPP	KA,A£,P =\[\begin{bmatrix} \frac{S_{AP}}{S_{A2P}} \\ \frac{S_{E=25}}{S_{A2P}} \end{bmatrix}	$K_{A,A\ell,p}$ $= \left[\frac{S_{Ap}}{S_{A\ell p}}\right]_{E=50 \text{ MeV}}$	$K_{A,A\ell,p}$ $= \left[\frac{S_{Ap}}{S_{A\ell p}}\right]_{E=75 \text{ MeV}}$	TRAPP		K	KA, AR, P = \[\begin{align*} \begi	
200 200	Aluminum Aluminum	2 100	2.38×10^{1} 1.84×10^{0}	2.36 × 10 ¹ 1.84 × 10 ⁰	2.40 × 10 ¹ 1.85 × 10 ⁰	2.42 × 10 ¹ 1.85 × 10 ⁰	2.72 × 10 ¹ 1.98 × 10 ⁰	2.77 × 10 ¹ 2.01 × 10 ⁰	2.81 × 10 ¹ 2.02 × 10 ⁰	2.83 × 10 ¹ 2.03 × 10 ⁰	
200 200	Polyethylene Polyethylene	_	2.29×10^{1} 1.05×10^{0}	2.27×10^{1} 9.50×10^{-1}	2.31×10^{1} 9.93×10^{-1}	2.32×10^{1} 1.01×10^{0}	2.62 × 10 ¹ 1.12 × 10 ⁰	2.65 × 10 ¹ 1.03 × 10 ⁰	2.70 × 10 ¹ 1.08 × 10 ⁰	2.72 × 10 ¹ 1.10 × 10 ⁰	
200 200	Copper Copper	2 100	2.42×10^{1} 2.34×10^{0}	2.40×10^{1} 2.51×10^{0}	2.44×10^{1} 2.45×10^{0}	2.45×10^{1} 2.42×10^{0}	2.76 × 10 ¹ 2.53 × 10 ⁰	2.82 × 10 ¹ 2.76 × 10 ⁰	2.86 × 10 ¹ 2.69 × 10 ⁰	2.88 × 10 ¹ 2.66 × 10 ⁰	
100 100	Aluminum Aluminum	2 100	6.61 × 10 ⁰ 5.40 × 10 ⁻²	6.48×10^{0} 5.39×10^{-2}	6.65 × 10 ⁰ 5.45 × 10 ⁻²	6.74×10^{0} 5.47×10^{-2}	7.98 × 10 ⁰ 6.03 × 10 ⁻²	8.08 × 10 ⁰ 6.16 × 10 ⁻²	8.31 × 10 ⁰ 6.22 × 10 ⁻²	8.41 × 10 ⁹ 6.24 × 10 ⁻²	
100 100	Polyethylene Polyethylene	2 100	6.18×10^{0} 1.83×10^{-2}	6.00×10^{0} 1.50×10^{-2}	6.19×10^{0} 1.63×10^{-2}	6.28×10^{0} 1.70×10^{-2}	7.45×10^{0} 2.03×10^{-2}	7.47×10^{0} 1.70×10^{-2}	7.71 × 10 ⁰ 1.85 × 10 ⁻²	7.82 × 10 ⁰ 1.92 × 10 ⁻²	
100 100	Copper Copper	2 100	6.78×10^{0} 8.58×10^{-2}	6.69×10^{0} 9.79×10^{-2}	6.85×10^{0} 9.37×10^{-2}	6.93×10^{0} 9.18×10^{-2}	8.20 × 10 ⁰ 9.62 × 10 ⁻²	8.35 × 10 ⁰ 1.12 × 10 ⁻¹	8.56 × 10 ⁰ 1.07 × 10 ⁻¹	8.66 × 10 ⁰	
50 50	Aluminum Aluminum	2 100	3.70 × 10 ⁻¹ 3.52 × 10 ⁻⁵	3.52×10^{-1} 3.48×10^{-5}	3.71×10^{-1} 3.55×10^{-5}	3.79×10^{-1} 3.58×10^{-5}	4.82 × 10 ⁻¹ 4.13 × 10 ⁻⁵	4.78×10^{-1} 4.21×10^{-5}	5.03×10^{-1} 4.29×10^{-5}	1.05×10^{-1} 5.15×10^{-1}	
50 50	Polyethylene Polyethylene	2 100	3.27 × 10 ⁻¹ 4.23 × 10 ⁻⁶	3.05×10^{-1} 2.82×10^{-6}	3.24×10^{-1} 3.32×10^{-6}	3.33 × 10 ⁻¹ 3.59 × 10 ⁻⁶	4.24 × 10 ⁻¹ 4.91 × 10 ⁻⁶	4.13 × 10 ⁻¹ 3.36 × 10 ⁻⁶	4.38 × 10 ⁻¹ 3.97 × 10 ⁻⁶	4.32×10^{-5} 4.51×10^{-1}	
50 50	Copper Copper	2 100	3.89 × 10 ⁻¹ 8.64 × 10 ⁻⁵	3.74×10^{-1} 1.11×10^{-4}	3.92 × 10 ⁻¹ 1.02 × 10 ⁻⁴	4.00 × 10 ⁻¹ 9.79 × 10 ⁻⁵	5.07 × 10 ⁻¹ 1.02 × 10 ⁻⁴	5.08 × 10 ⁻¹ 1.36 × 10 ⁻⁴	5.33 × 10 ⁻¹ 1.24 × 10 ⁻⁴	4.29×10^{-6} 5.44×10^{-1} 1.19×10^{-4}	

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TABLE 6.5

Sensitivity of Dose Results Obtained with the Equivalent-Thickness Approximation to the choice of KA,AL,a for Incident Solar-Flare Alpha-Particle Spectra

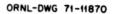
			Unatten	(r _T - 1	l pha-Particle Abo 5 g cm ⁻²) ad)	sorbed Dose	Unattenuated Primary Alpha-Particle Dose Equivalent (r _T = 15 g cm ⁻²) (rem)				
Character- istic Rigidity (MV)	Shield Haterial	Shield Thickness (g cm ⁻²)	TRAPP	$K_{A,AL,\alpha}$ $= \begin{bmatrix} \frac{S_{A\alpha}}{S_{AL\alpha}} \end{bmatrix}_{E=100 \text{ M}}$	KA,A£,a -[SAa] SAea] E-150 Me	KA,A£,a =\[\left[\frac{S_{Aa}}{S_{Ata}} \right]_{E=200 MeV}	TRAPP	K _{A, Al, a}	K _{A,AL,a}	KA, At, a SAC E=200 MeV	
200 200	Aluminus Aluminum	100	8.11 × 10° 6.69 × 10 ⁻²	7.93 × 10 ⁰ 6.68 × 10 ⁻²	8.06 × 10 ⁰ 6.72 × 10 ⁻²	8.14 × 10 ⁰ 6.74 × 10 ⁻²	1.84 × 10 ¹ 1.16 × 10 ⁻¹	1.85 × 10 ¹ 1.19 × 10 ⁻¹	1.88 × 10 ¹ 1.20 × 10 ⁻¹	1.90 × 10 ¹	
200 200	Polyethylene Polyethylene	100	7.58×10^{0} 2.25×10^{-2}	7.35×10^{0} 1.84×10^{-2}	7.49 × 10 ⁰ 1.94 × 10 ⁻²	7.58×10^{0} 2.01×10^{-2}	1.71 × 10 ¹ 3.81 × 10 ⁻²	1.70 × 10 ¹ 3.20 × 10 ⁻²	1.74 × 10 ¹ 3.38 × 10 ⁻²	1.20×10^{-1} 1.76×10^{1}	
200 200	Copper Copper	2 100	8.32×10^{0} 1.06×10^{-1}	8.19 × 10 ⁰ 1.21 × 10 ⁻¹	8.31 × 10 ⁰ 1.18 × 10 ⁻¹	8.38×10^{0} 1.16×10^{-1}	1.89 × 10 ¹ 1.89 × 10 ⁻¹	1.91×10^{1} 2.21×10^{-1}	1.95 × 10 ¹ 2.15 × 10 ⁻¹	3.49 × 10 ⁻² 1.97 × 10 ¹	
100 100	Aluminum Aluminum	100	1.40 × 10 ⁻¹ 1.37 × 10 ⁻⁵	1.33 × 10 ⁻¹ 1.36 × 10 ⁻⁵	1.37 × 10 ⁻¹ 1.37 × 10 ⁻⁵	1.40 × 10 ⁻¹ 1.38 × 10 ⁻⁵	3.89 × 10 ⁻¹ 2.86 × 10 ⁻⁵	3.81 × 10 ⁻¹ 2.91 × 10 ⁻⁵	3.94 × 10 ⁻¹ 2.95 × 10 ⁻⁵	2.11×10^{-1} 4.02×10^{-1}	
100 100	Polyethylene Polyethylene	2 100	1.23 × 10 ⁻¹ 1.67 × 10 ⁻⁶	1.15 × 10 ⁻¹ 1.12 × 10 ⁻⁶	1.19×10^{-1} 1.24×10^{-6}	1.22×10^{-1} 1.32×10^{-6}	3.40×10^{-1} 3.34×10^{-6}	3.28 × 10 ⁻¹ 2.30 × 10 ⁻⁶	3.41 × 10 ⁻¹ 2.55 × 10 ⁻⁶	2.97×10^{-5} 3.49×10^{-1}	
100 100	Copper	2 100	1.47 × 10 ⁻¹ 3.35 × 10 ⁻⁵	1.41 × 10 ⁻¹ 4.31 × 10 ⁻⁵	1.45 × 10 ⁻¹ 4.09 × 10 ⁻⁵	1.48×10^{-1} 3.96×10^{-5}	4.11 × 10 ⁻¹ 7.12 × 10 ⁻⁵	4.06 × 10 ⁻¹ 9.45 × 10 ⁻⁵	4.18 × 10 ⁻¹ 8.96 × 10 ⁻⁵	2.72 × 10 ⁻⁶ 4.26 × 10 ⁻¹	
50 50	Aluminum Aluminum	2 100	3.01×10^{-5} 4.27×10^{-13}	2.68×10^{-5} 4.12×10^{-13}	2.85 × 10 ⁻⁵ 4.22 × 10 ⁻¹³	2.96×10^{-5} 4.28×10^{-13}	1.04 × 10 ⁻⁴ 1.09 × 10 ⁻¹²	9.59 × 10 ⁻⁵ 1.09 × 10 ⁻¹²	1.02 × 10 ⁻⁴ 1.12 × 10 ⁻¹²	8.66 × 10 ⁻⁵ 1.06 × 10 ⁻⁴	
	Polyethylene Polyethylene	2 100	2.36 × 10 ⁻⁵ 6.67 × 10 ⁻¹⁵	2.04 × 10 ⁻⁵ 2.96 × 10 ⁻¹⁵	2.18×10^{-5} 3.63×10^{-15}	2.28×10^{-5} 4.10×10^{-15}	8.12 × 10 ⁻⁵ 1.64 × 10 ⁻¹⁴	7.23 × 10 ⁻⁵ 7.50 × 10 ⁻¹⁵	7.77 × 10 ⁻⁵ 9.20 × 10 ⁻¹⁵	1.13 × 10 ⁻¹² 8.12 × 10 ⁻⁵ 1.04 × 10 ⁻¹⁴	
	Copper Copper	2 100	3.31×10^{-5} 2.50×10^{-12}	3.02×10^{-5} 4.07×10^{-12}	3.18×10^{-5} 3.68×10^{-12}	3.29×10^{-5} 3.44×10^{-12}	1.15 × 10 ⁻⁴ 6.52 × 10 ⁻¹²	1.08 × 10 ⁻⁴ 1.10 × 10 ⁻¹¹	1.14 × 10 ⁻⁴ 9.92 × 10 ⁻¹²	1.18 × 10 ⁻⁴ 9.28 × 10 ⁻¹²	

6.6 THE VALIDITY OF THE ANALYTIC STOPPING-POWER APPROXIMATION

An analytic stopping-power approximation was described in Section 3.6, and information on the extent to which the proton and alpha-particle stopping powers could be fitted by expressions of the form described in Section 3.6 was given in Section 4.4. In this section, the validity of using the analytic expressions for the stopping powers is examined by comparing calculated dose results obtained using the approximate expressions with calculated dose results obtained without the approximation.

All of the calculated data presented in this section are for the geometry shown in Fig. 3.1 with $\rm r_T=15~g~cm^{-2}$. All of the dose values given are for the center of the tissue sphere and were obtained using the unattenuated primary-particle flux or fluence per unit energy. The incident particle flux or fluence per unit energy in all cases is that described in Sections 2.1.5 and 2.2.2. In the case of incident alpha particles, results are given for two different sets of analytic stopping-power parameters. In one series of calculations, the alpha-particle parameters given by Hill et al. 80 were used, and in a second series of calculations, the alpha-particle parameters obtained by scaling the proton parameters of Hill et al. (see Eqs. 4.15 to 4.17) were used. All of the calculations described in this section were done with the code TRAPP.

The absorbed-dose rate and the dose-equivalent rate, respectively, at the center of the tissue sphere are shown in Figs. 6.36 and 6.37 as a function of shield thickness for several incident Van Allen belt spectra and several materials. The solid-line curves, labeled "TRAPP," give the dose rates when the energy-dependent stopping powers shown in Fig. 4.1 are used. The plotted points give the dose rates when the analytic expressions for the



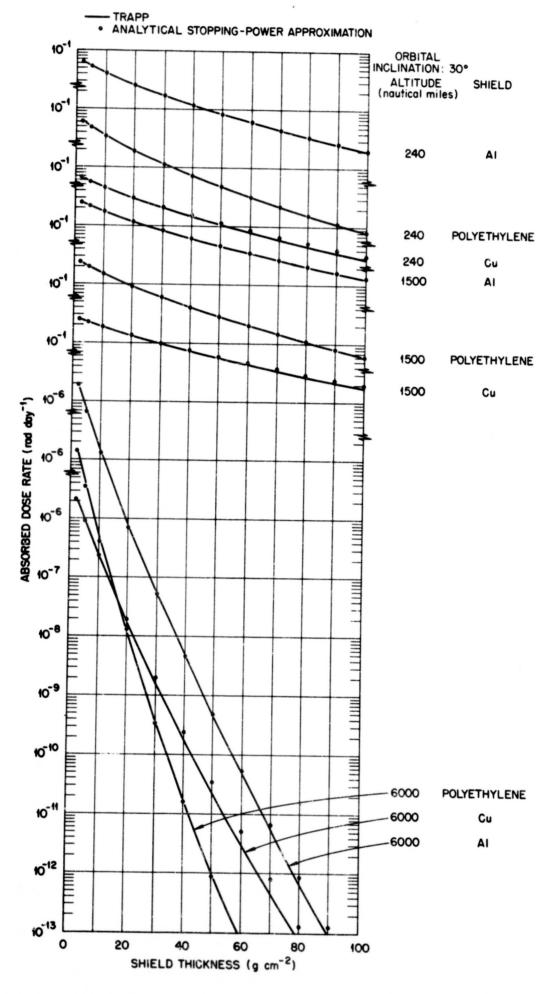


Fig. 6.36. Absorbed-dose rate from unattenuated primary protons at the center of the tissue sphere vs spherical-shell-shield thickness for various incident Van Allen belt spectra.

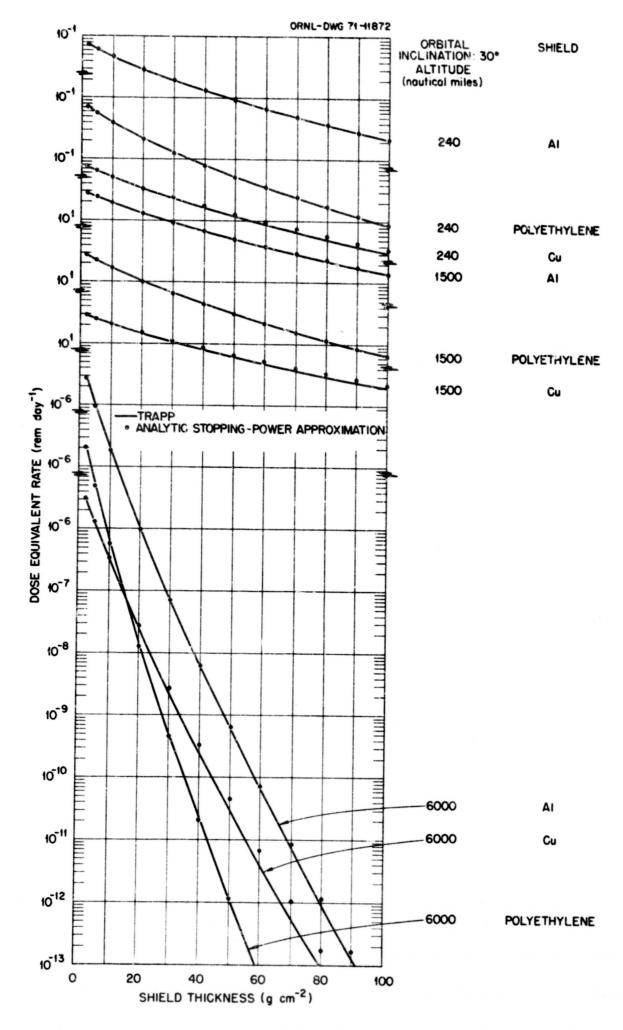


Fig. 6.37. Dose-equivalent rate from unattenuated primary protons at the center of the tissue sphere vs spherical-shell-shield thickness for various incident Van Allen belt spectra.

proton stopping powers are used. For the thinner shields (\leq 30 g cm⁻²), the plotted points and solid curves are in good agreement in all cases considered in both Figs. 6.36 and 6.37. For the thicker shields and particularly for the softer incident spectra, there are some differences between the plotted points and the solid curves. In the figures, the error introduced by the analytic stopping-power approximation appears to be largest in the case of a copper shield and smallest in the case of a polyethylene shield. In this regard, however, it must be remembered that the parameter h_p has been taken to be the same for all materials and, on the basis of the results shown in Table 4.2, the value used (h_p = 1.775) is not the optimum choice for all of the materials considered. It must also be remembered, however, that when the analytic stopping-power approximation is used in the manner described in Section 3.6 the value of h_p must be chosen to be the same for all materials in the shield.

The absorbed dose and dose equivalent, respectively, at the center of the tissue sphere are shown in Figs. 6.38 and 6.39 as a function of shield thickness for several incident solar-flare proton spectra and for several shield materials. The solid curves and plotted points in Figs. 6.38 and 6.39 have the same meanings as in Figs. 6.36 and 6.37, and the comparisons in Figs. 6.38 and 6.39 are very similar to those shown in Figs. 6.36 and 6.37.

The absorbed dose and dose equivalent, respectively, at the center of the tissue sphere are shown in Figs. 6.40 and 6.41 as a function of shield thickness for several incident solar-flare alpha-particle spectra and for several shield materials. The solid curves and plotted points have the same meanings as in Figs. 6.36 to 6.39. The analytic stopping-power parameters given by Hill et al.80 were used in obtaining the plotted points shown

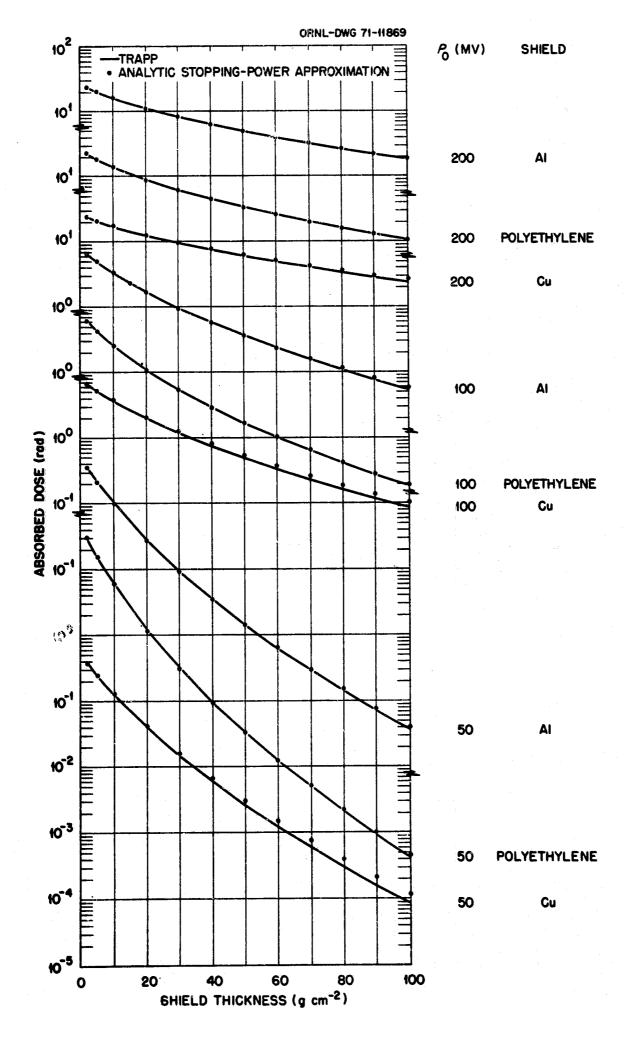


Fig. 6.38. Absorbed dose from unattenuated primary protons at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare proton spectra.

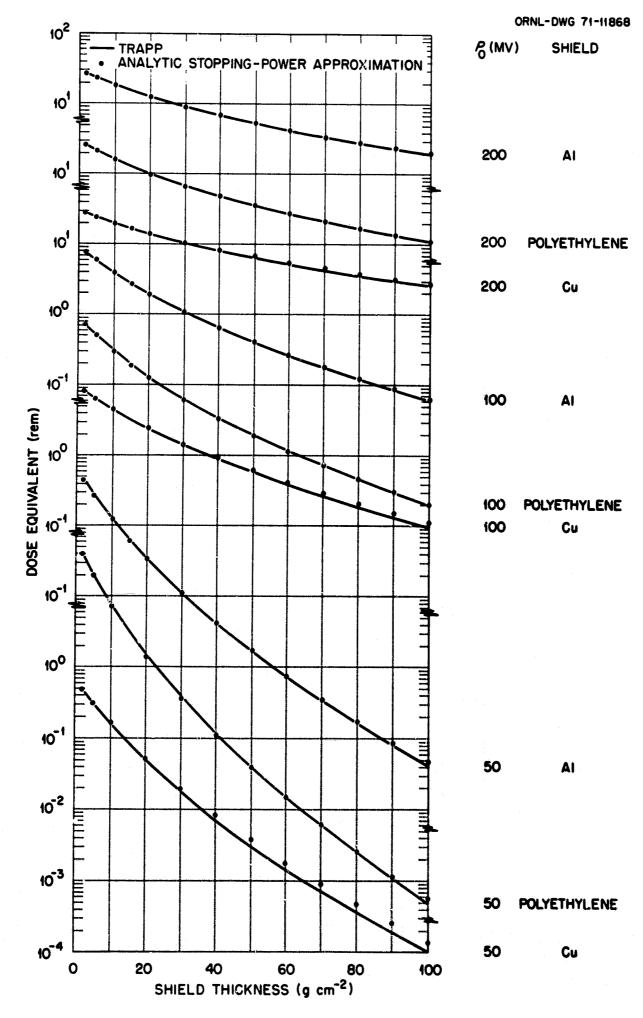


Fig. 6.39. Dose equivalent from unattenuated primary protons at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare proton spectra.

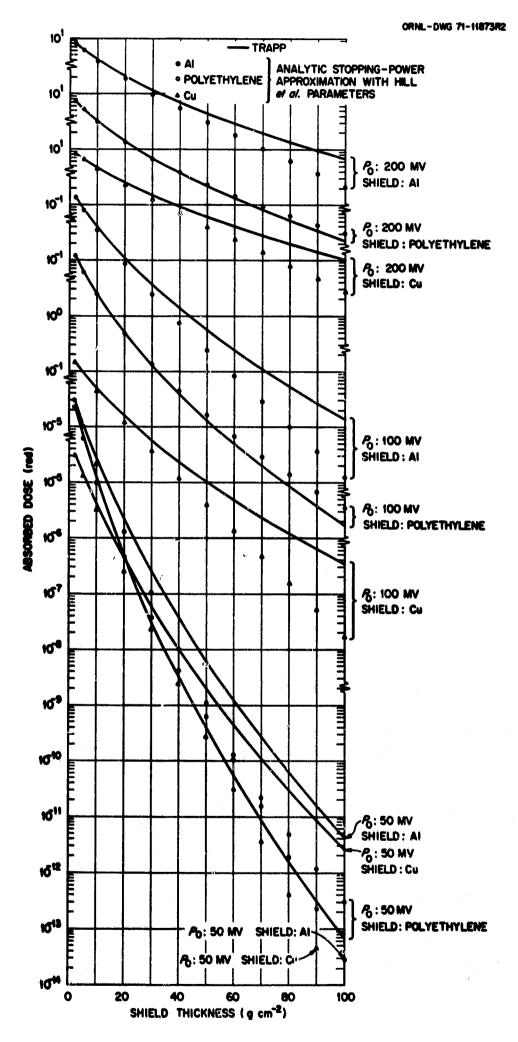


Fig. 6.40. Absorbed dose from unattenuated primary alpha particles at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare alpha-particle spectra.

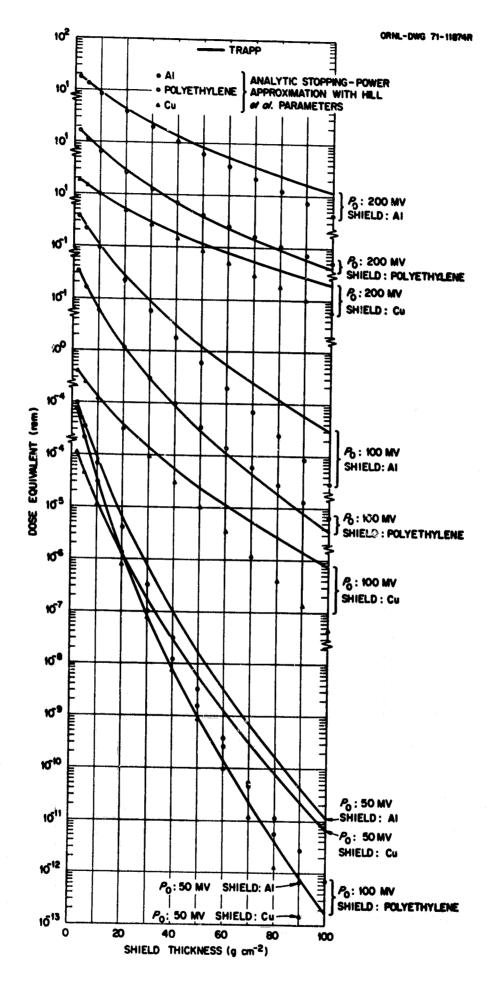


Fig. 6.41. Dose equivalent from unattenuated primary alpha particles at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare alpha-particle spectra.

in Figs. 6.40 and 6.41. The errors introduced by the analytic stopping-power approximation with the parameters of Hill $et\ al$. in the case of incident alpha particles become very large as the shield thickness increases. The poor results shown in Figs. 6.40 to 6.41 are probably to be attributed to the fact that the analytic stopping-power expression with the parameters of Hill $et\ al$. does not represent at all well the alpha-particle stopping power at energies above ~ 1 GeV (see Fig. 4.8).

Absorbed-dose and dose-equivalent results analogous to those shown in Figs. 6.40 and 6.41 are presented in Figs. 6.42 and 6.43. The solid curves in Figs. 6.42 and 6.43 are the same as those in Figs. 6.40 and 6.41. The plotted points were obtained using the analytic stopping-power approximation with parameters obtained by using the proton parameters of Hill et al.

(h_p = 1.775 for all materials) and the scaling law expressed by Eqs. 4.15 to 4.17. The errors introduced by using the analytic stopping-power approximation with the scaled parameters are not excessive, except possibly for very steep incident spectra and very thick shields, and are considerably smaller than those introduced by using the Hill et al. analytic stopping-power parameters. On the basis of the results in Figs. 6.40 to 6.43, it seems clear that when the analytic stopping-power approximation is used for incident alpha particles, the parameters should be obtained by scaling the proton parameters.

In general, the analytic stopping-power approximation, with appropriately chosen parameters, gives reliable results for both protons and alpha particles and therefore can be used to substantially reduce the computational effort required to carry out space-shielding calculations based on unattenuated primary particles only.

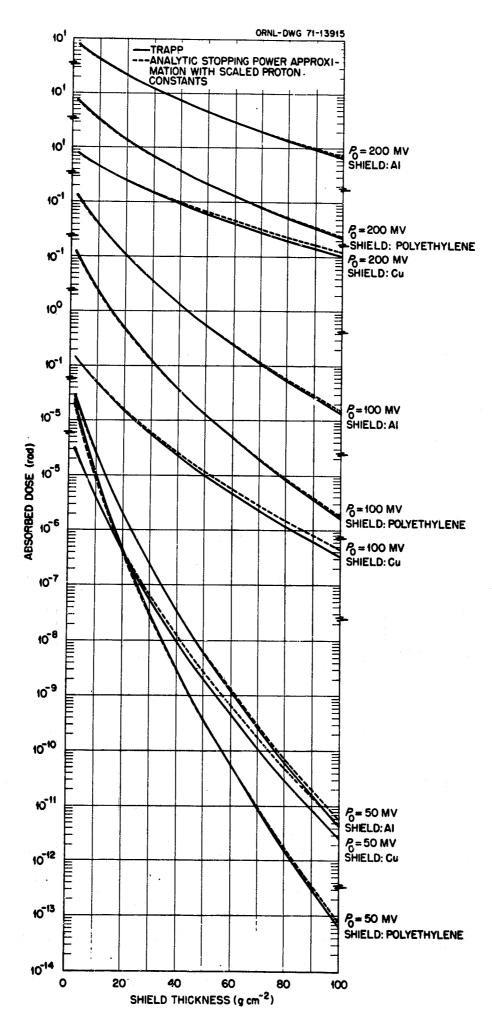


Fig. 6.42. Absorbed dose from unattenuated primary alpha particles at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare alpha-particle spectra.

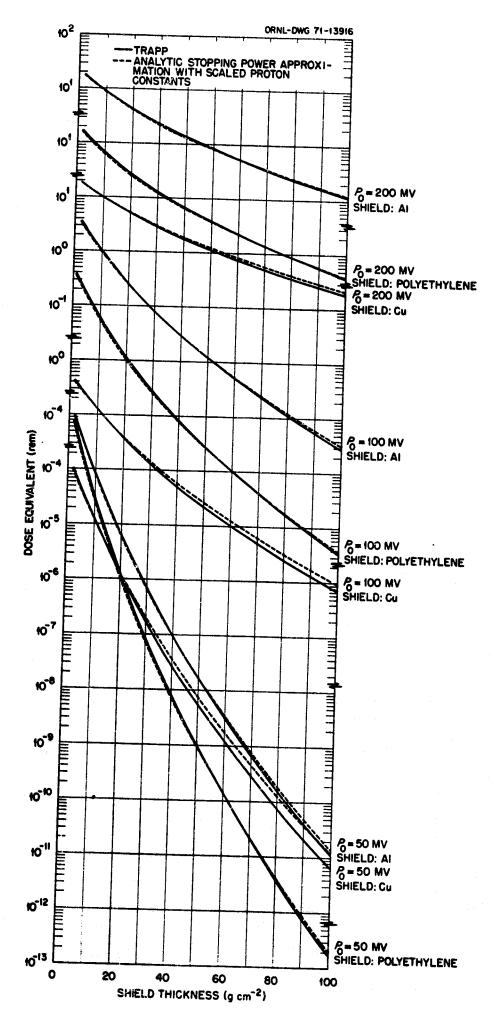


Fig. 6.43. Dose equivalent from unattenuated primary alpha particles at the center of the tissue sphere vs spherical-shell-shield thickness for various incident solar-flare alpha-particle spectra.

6.7 THE USE OF THE EQUIVALENT-THICKNESS APPROXIMATION AND THE ANALYTIC STOPPING-POWER APPROXIMATION IN COMPLEX GEOMETRIES

In the previous two sections, the validity of the equivalent-thickness approximation and the analytic stopping-power approximation has been considered in the case of a simple geometry, i.e., in the case of the dose at the center of the geometric configuration shown in Fig. 3.1. The power of these approximation methods lies in the fact that they may be used to obtain dose estimates in very complex geometric structures such as actual space-craft. In this section, results obtained with the code MEVDP, 75 which utilizes the equivalent-thickness approximation and which is capable of treating complex geometries, and results obtained with the code LSVDC4, 78 which utilizes the analytic stopping-power approximation and which is capable of treating complex geometries, are presented and compared. The calculated dose results obtained with MEVDP and LSVDC4 are also compared with calculated dose results that include a contribution from particles produced by nuclear reactions.

The geometry considered in this section is that shown in Fig. 3.1 with r_T = 15 g cm⁻². In this section, however, dose results are presented as a function of depth in the tissue sphere, while in Sections 6.5 and 6.6 dose results are presented only at the center of the tissue sphere. The codes MEVDP and LSVDC4 are capable of treating much more complex geometries than that shown in Fig. 3.1. However, the calculation of the dose at points other than the center of the tissue sphere tests the ability of the code to treat complex geometries; i.e., the angular integrations in Eqs. 3.15 and 3.16 cannot be carried out trivially, and in this geometry the calculated results obtained with MEVDP and LSVDC4 may be compared with those from NMTC presented in Section 6.2.

The equivalent-thickness approximation usually used in MEVDP is slightly different from that described in Section 3.5 in that in MEVDP the equivalentthickness approximation is based on an assumed analytic form for the stopping power as a function of energy. Since the equivalent-thickness approximation constants are inputs to MEVDP, it is possible to utilize in the code the form of the approximation described in this report, and this has been done; i.e., in the calculations reported later in this section, the equivalent material has been taken to be aluminum and the constants used are those given by Eqs. 4.10 and 4.11. To carry out the dose calculations, it is necessary to know the dose as a function of the thickness of the equivalent material. In the version of MEVDP available from the Radiation Shielding Information Center, these dose values must be supplied by the user. calculations reported here, the dose values from unattenuated primary particles in aluminum obtained from TRAPP and given in Appendix 2 were used. Dose values at shield thicknesses not explicitly given in Appendix 2 were obtained using 3-point Lagrangian interpolation. As an option, one may obtain from MEVDP a least-square fit to the cumulative solid-angle-vs-thickness data obtained with the code. This option can be useful in treating very complex geometries, but it was not utilized in the calculations presented here; i.e., the dose calculations were obtained by summing the contribution from each solid-angle element considered in MEVDP.

The code LSVDC4* utilizes the analytic stopping-power approximation in the form described in Section 3.6. In the calculations for incident protons, the value $h_p = 1.775$ with the associated values of a_{AP} and b_{AP} given by

^{*}There is in LSVDC4 an option for including in an approximate manner the contribution from nuclear-reaction products. This option was not used in the work reported here.

Hill et αl . (see Table 4.2) was used for all materials. The only exception to this statement is that the value $h_p = 1.800$ was used for tissue in the dose integrals since the value of h_p for tissue in the dose integrals does not have to correspond to the value of h_p used in the transport calculations. In the calculations for incident alpha particles, the analytic stopping-power parameters given by the scaling Eqs. 4.15 to 4.17 and the proton parameters $h_p = 1.775$ have been used for all materials. The analytic stopping-power parameters for alpha particles given by Hill et αl . have not been considered in this section because of the large errors shown in Figs. 6.40 and 6.41.

The absorbed-dose rate is shown in Fig. 6.44 as a function of depth in the tissue sphere for a variety of incident Van Allen belt proton spectra, shield thicknesses, and shield materials. The histogram gives the results when secondary-particle production and transport are included. The histogram data are the same as those shown in Fig. 6.22. The solid curves give the results obtained with MEVDP and the plotted points show the results obtained with LSVDC4. For an incident Van Allen belt spectrum corresponding to an altitude of 6000 nautical miles and an orbital inclination of 30°, absorbed-dose-rate results from LSVDC4 are not given in the figure because it has been found that this code is not operable for very steep incident spectra.*

In both MEVDP and LSVDC4, the absorbed-dose rate is calculated with the unattenuated primary-particle flux. The differences between the MEVDP results and the NMTC results shown in the figure are due to the use of the

^{*}In LSVDC4 the incident energy spectrum is fitted by a series of power laws in different energy regions. In the case of a very steep incident spectrum, the numerical procedure used to determine these power-law fits leads to very large numbers, and the code will not operate because of "exponential over-flows."

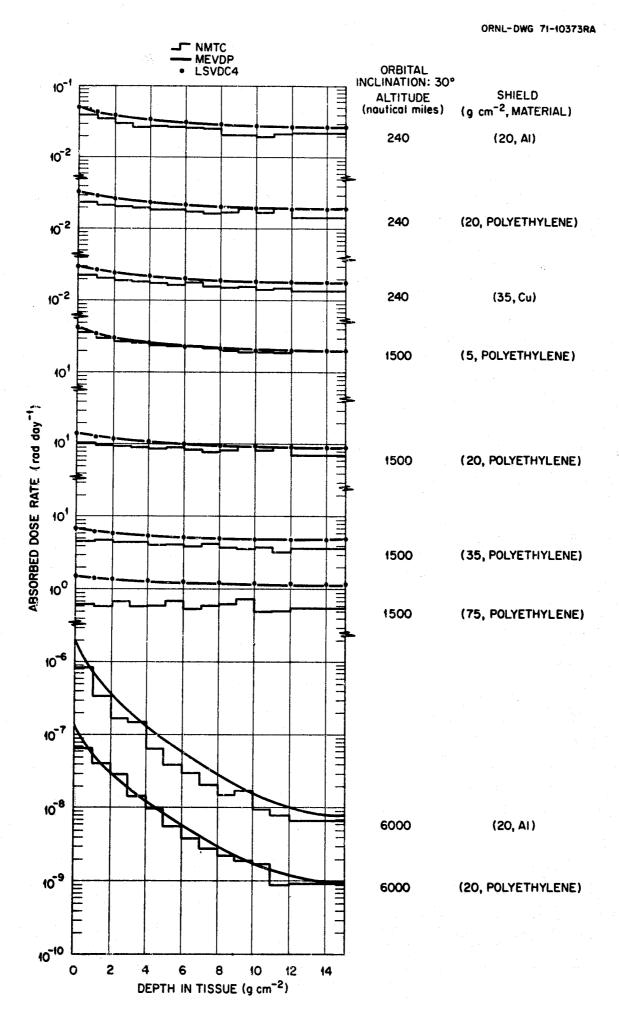


Fig. 6.44. Absorbed-dose rate vs depth in tissue for Van Allen belt proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

unattenuated primary-particle flux and to the use of the equivalent-thickness approximation in MEVDP. The differences between the LSVDC4 results and the NMTC results shown in the figure are due to the use of the unattenuated primary-particle flux in LSVDC4 and to the use of the analytic stopping-power approximation in LSVDC4. It is interesting to note that the errors introduced by using MEVDP and LSVDC4 are very approximately independent of tissue depth and lead to an overestimate of the absorbed-dose rate. This overestimation increases with shield thickness in the geometry being considered. In all cases where absorbed-dose-rate results from both MEVDP and LSVDC4 are given, they are in excellent agreement.

In Fig. 6.45 the dose-equivalent rate as a function of depth in tissue is shown for a variety of incident Van Allen belt spectra, shield thicknesses, and shield materials. The histograms show the results from NMTC and the solid lines show the results from MEVDP. Results from LSVDC4 are not shown since this code does not calculate the dose-equivalent rate. It should be noted that for most of the cases considered and at all tissue depths the dose-equivalent rate from MEVDP is a good approximation to the dose-equivalent rate from NMTC.

The absorbed dose and dose equivalent, respectively, are shown in Figs. 6.46 and 6.47 as a function of depth in tissue for a variety of incident solar-flare proton spectra, shield thicknesses, and shield materials. The histograms, curves, and points have the same meanings in Figs. 6.46 and 6.47 as in Figs. 6.44 and 6.45. In Fig. 6.46 results from LSVDC4 are not given for $P_{\rm O}$ = 50 MV because this spectrum is too steep to be treated (see footnote on page 200). The same difficulty that prevents LSVDC4 from operating for an incident spectrum with $P_{\rm O}$ = 50 MV also prevents the treatment

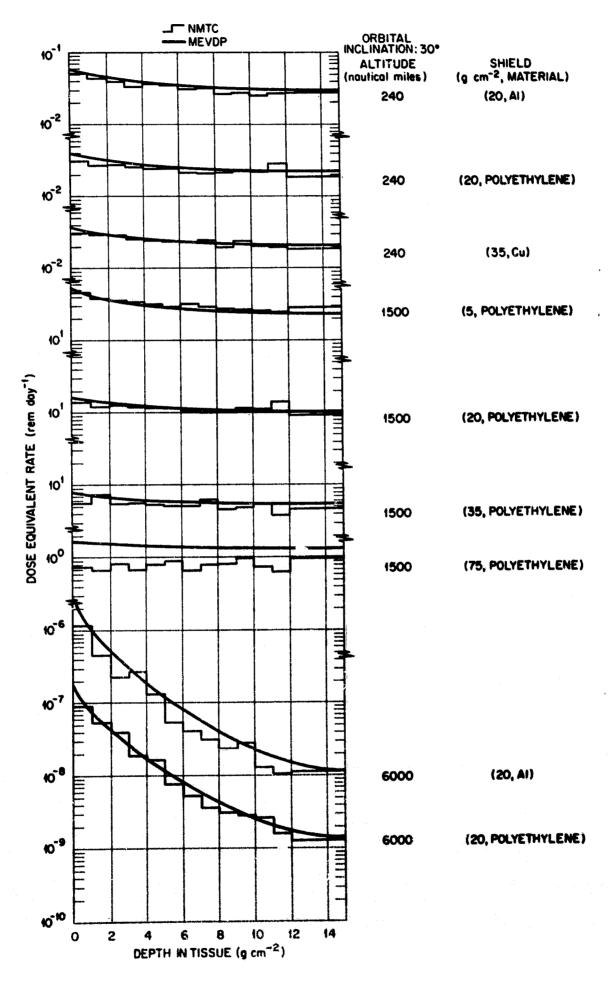


Fig. 6.45. Dose-equivalent rate vs depth in tissue for Van Allen belt proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

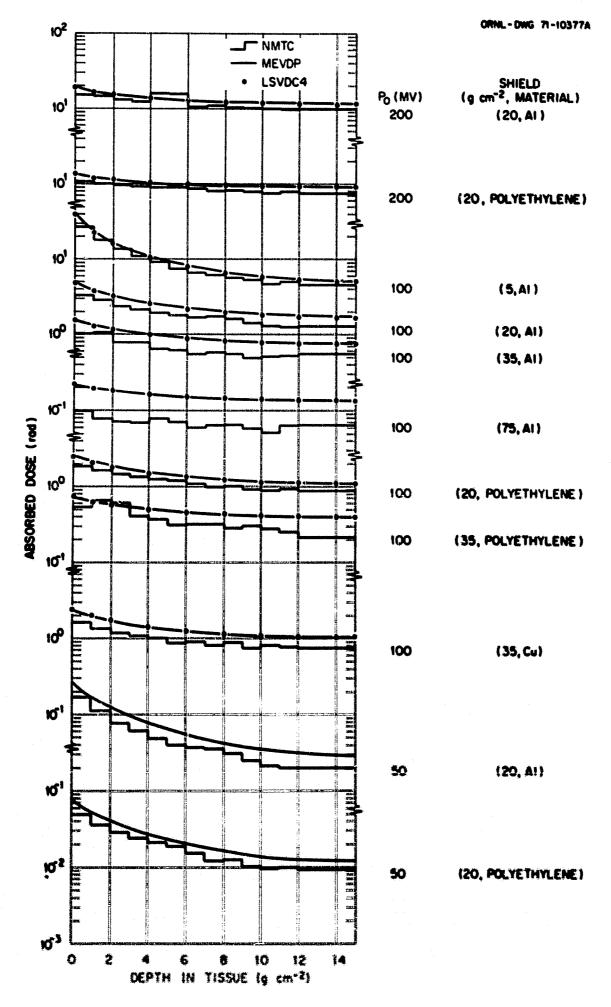


Fig. 6.46. Absorbed dose vs depth in tissue for solar-flare proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

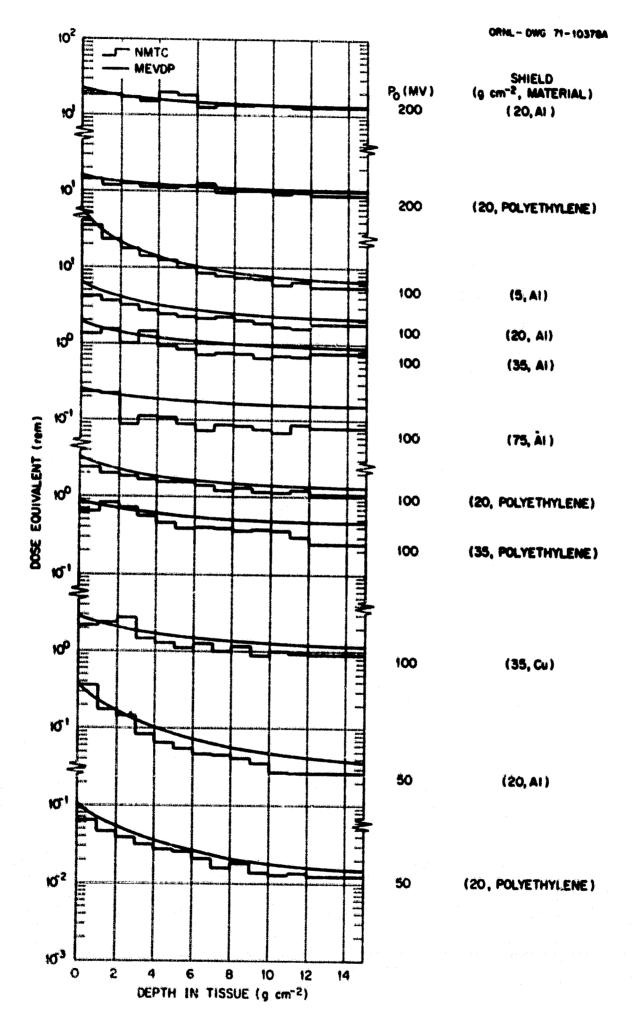


Fig. 6.47. Dose equivalent vs depth in tissue for solar-flare proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

of the higher energy (\geq 1000 MeV) incident protons in the case of $P_0 = 100$ MV and $P_0 = 200$ MV. However, for the shield thicknesses considered in Fig. 6.46, these higher energy incident protons do not contribute appreciably to the absorbed dose and may be neglected.

The absorbed dose and dose equivalent, respectively, for a variety of incident solar-flare alpha-particle spectra, shield materials, and shield thicknesses are presented in Figs. 6.48 and 6.49. The solid curves in both figures show the results from MEVDP and the plotted points in Fig. 6.48 show the results from LSVDC4. Results from NMTC are not given since this code is not capable of treating incident alpha particles. Results from LSVDC4 for P_o = 50 MV are not given in Fig. 6.48 since this code is not operable for this incident spectrum. In the case of $P_0 = 100 \text{ MV}$, it was possible in LSVDC4 to treat incident alpha particles of ≤ 1500 MeV. The error caused by neglecting these higher energy alpha particles is not appreciable for most of the shield thicknesses considered. The absorbed dose from LSVDC4 in the case of an aluminum shield of $75-g-cm^{-2}$ thickness, however, is somewhat less than that given by MEVDP, and this may be due to the higher energy particles that were neglected in LSVDC4. Since the contribution to the absorbed dose and dose equivalent from particles produced by nuclear reactions is not known in the case of incident alpha particles, the errors associated with the data given in Figs. 6.48 and 6.49 are not known. However, because of the lack of more definitive information, it seems reasonable to accept the dose results in Figs. 6.48 and 6.49 as estimates of the doses as a function of depth in the tissue from incident solar-flare alpha-particle spectra.

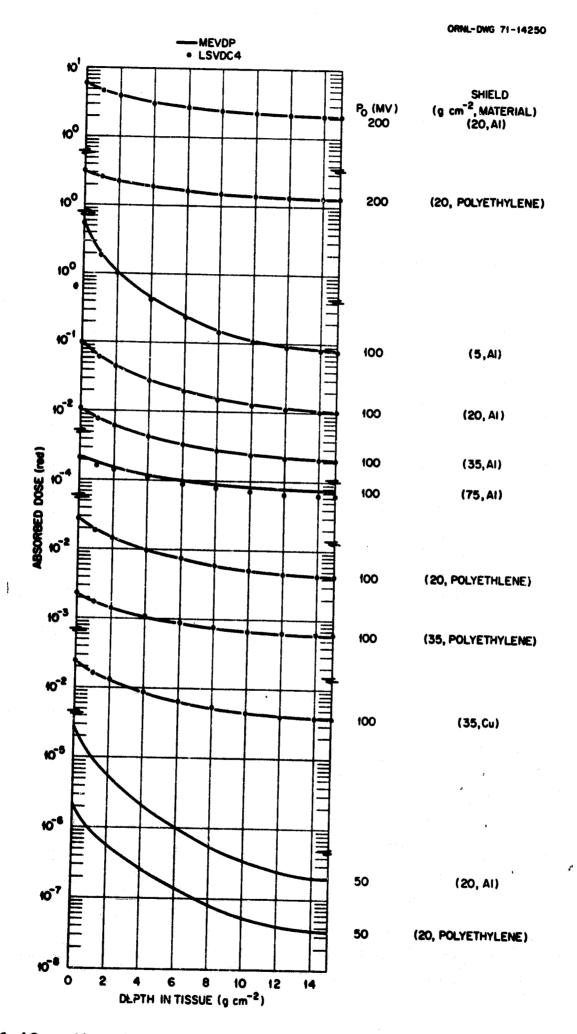


Fig. 6.48. Absorbed dose vs depth in tissue for solar-flare alphaparticle spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

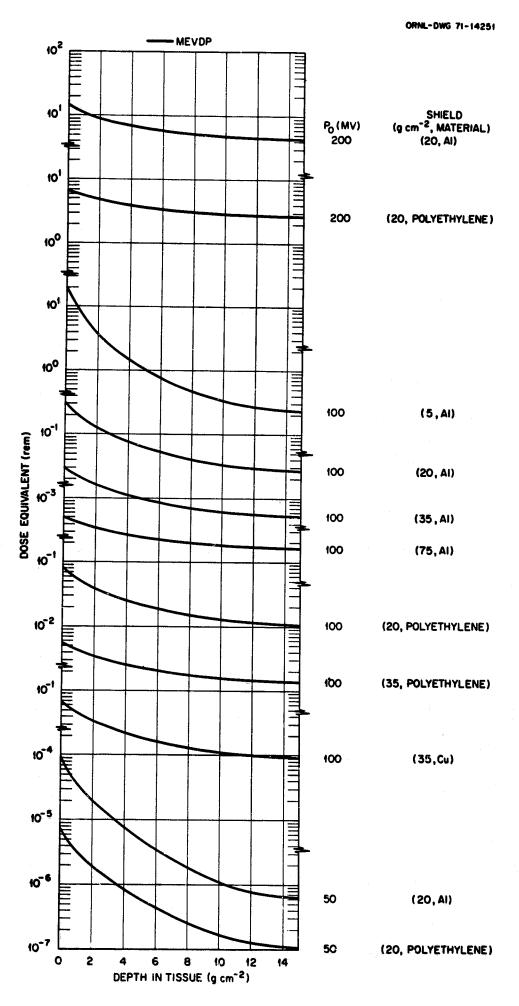


Fig. 6.49. Dose equivalent vs depth in tissue for solar-flare alphaparticle spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

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Chapter 7

THE CALCULATED ABSORBED-DOSE RATE AND DOSE-EQUIVALENT RATE FROM GALACTIC COSMIC-RAY PROTONS

In this chapter numerical results pertaining to the shielding of space vehicles against galactic cosmic-ray protons are presented and discussed. The interesting case of galactic cosmic-ray proton bombardment of the moon is not considered here, but calculated results for this case may be found in Refs. 35 and 108. Shielding against the heavier galactic cosmic rays is not considered in this chapter because the differential cross-section data required to take into account the production and transport of the nuclear-reaction products produced by these heavier nuclei are not available. Some very approximate information on shielding against galactic cosmic-ray alpha particles and heavier nuclei is given in Appendix 4.

7.1 THE SECONDARY-PARTICLE CONTRIBUTION TO THE ABSORBED-DOSE RATE AND DOSE-EQUIVALENT RATE FOR INCIDENT GALACTIC COSMIC-RAY PROTONS

Because of the higher energies involved, shielding calculations that include the secondary particles produced by nuclear interactions and the transport of these particles are more difficult in the case of incident galactic cosmic-ray protons than in the case of incident Van Allen belt and solar-flare protons. However, a computer code, HETC, 70,71 capable of carrying out such calculations is available, and therefore in typical cases estimates of the secondary-particle contribution to the absorbed-dose rate and to the dose-equivalent rate can be obtained. The differential particle-production cross sections at energies above 3 GeV, which are used in HETC,

^{108.} T. W. Armstrong, "Calculation of the Lunar Photon Albedo from Galactic and Solar Proton Bombardment," J. Geophys. Res. 77, 524 (1972).

are very approximate, 109 but nevertheless calculated results obtained with HETC have been found to be in good agreement with experimental data. 35 ,71 In this section, the results of calculations carried out with HETC for the geometry shown in Fig. 3.1 and $r_T = 15 \text{ g cm}^{-2}$ are presented and discussed. The details of the calculations and some additional results are given in Appendix 3.

Calculations have been carried out for the solar-minimum proton spectrum shown in Fig. 2.20, isotropically incident on aluminum shields of thicknesses of 5, 20, and 35 g cm^{-2} and for the solar-maximum proton spectrum shown in Fig. 2.20, isotropically incident on a 35-g-cm⁻²-thick aluminum shield. The contributions to the absorbed-dose rate are shown in Fig. 7.1 as a function of depth in the tissue sphere for the case of the solar-minimum proton spectrum incident on the 20-g-cm⁻²-thick aluminum shield. The contributions to the dose-equivalent rate are shown in Fig. 7.2 as a function of depth in the tissue sphere for the same case. The individual histograms in Figs. 7.1 and 7.2 have the same meanings as those in Figs. 6.18 to 6.20. The total absorbed-dose rate and total dose-equivalent rate are obtained by adding the individual contributions in Figs. 7.1 and 7.2, respectively. In Fig. 7.1 the primary protons and secondary protons are the major contributors to the absorbed-dose rate. In Fig. 7.2 the primary protons, the secondary protons, and the heavy nuclei are the major contributors to the total doseequivalent rate. Figures analogous to Figs. 7.1 and 7.2 for the other cases considered in this section are presented in Appendix 3.

^{109.} T. A. Gabriel, R. G. Alsmiller, Jr., and M. P. Guthrie, "An Extrapolation Method for Predicting Nucleon and Pion Differential Production Cross Sections from High-Energy (> 3 GeV) Nucleon-Nucleus Collisions," Oak Ridge National Laboratory Report ORNL-4542, 1970.

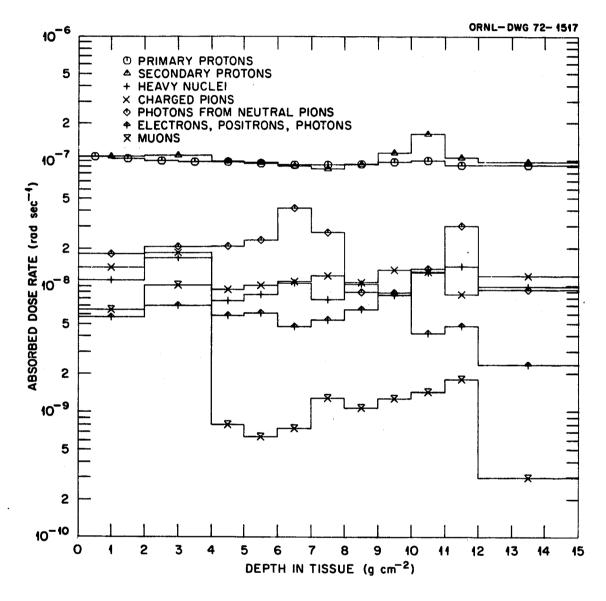


Fig. 7.1. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a galactic cosmic-ray solar-minimum proton spectrum is isotropically incident on a 20-g-cm⁻²-thick aluminum shield (see Fig. 3.1).

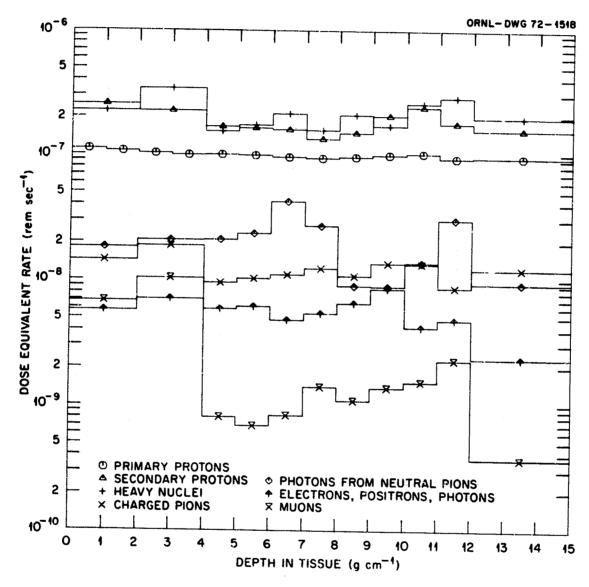


Fig. 7.2. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a galactic cosmic-ray solar-minimum proton spectrum is isotropically incident on a 20-g-cm⁻²-thick aluminum shield (see Fig. 3.1).

The total absorbed-dose rate, i.e., the absorbed-dose rate with the contribution from primary protons and all secondary particles included, and the absorbed-dose rate from attenuated primary protons are shown in Fig. 7.3 as a function of depth in the tissue for the four cases considered here. The total absorbed-dose rate is shown by the solid histograms and the attenuated primary-proton absorbed-dose rate is shown by the dashed histograms. In Fig. 7.4 analogous results for the dose-equivalent rate are presented. The plotted points at 15 g cm⁻², labeled "unattenuated primary protons" in Figs. 7.3 and 7.4, will be discussed in the next section. It should be noted that the results in Figs. 7.3 and 7.4 are given on a per-second basis. To obtain the doses that would be received on extended missions outside the earth's magnetosphere the values given must be multiplied by the mission duration in seconds.

The difference between the solid- and dashed-line histograms gives the secondary-particle contribution to the total dose. In contrast to the results shown in Figs. 6.18 to 6.20 for Van Allen belt and solar-flare incident spectra, the secondary particles in the case of incident galactic cosmic-ray protons contribute appreciably to the absorbed-dose rate and dose-equivalent rate. This is particularly true in the case of the dose-equivalent rate and the thicker shields considered. For all of the cases considered, the total and the primary-proton absorbed-dose rates and the total and the primary-proton dose-equivalent rates are very approximately constant as a function of tissue depth.

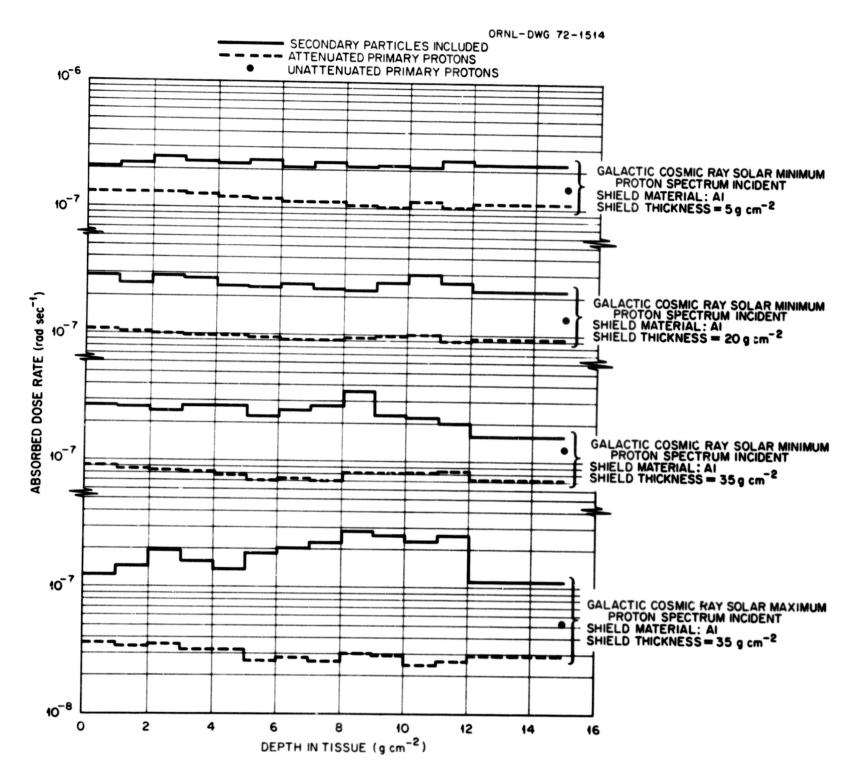


Fig. 7.3. Absorbed-dose rate vs depth in tissue for galactic cosmicray proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

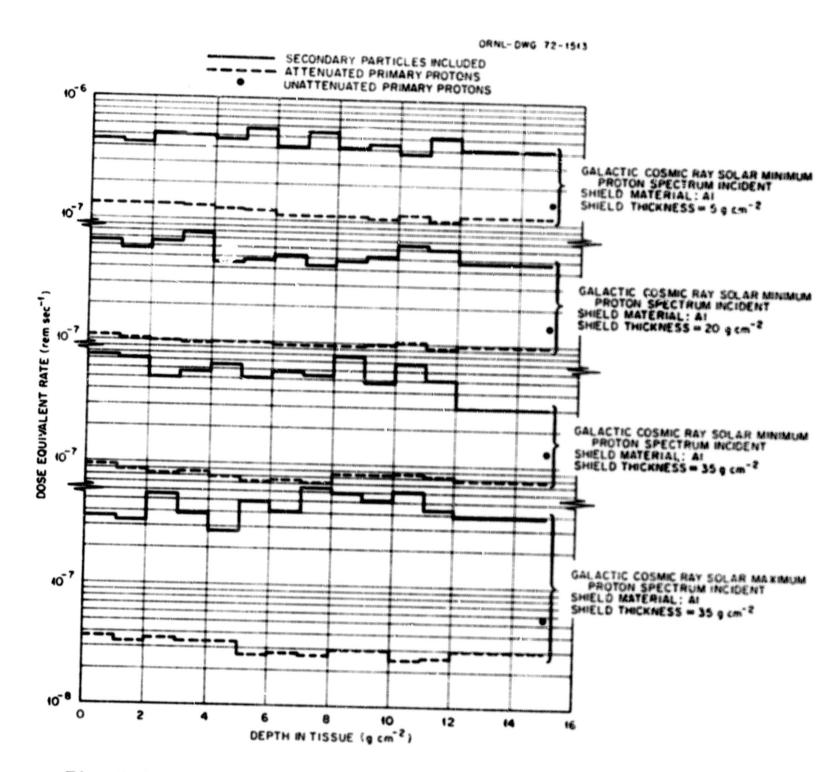


Fig. 7.4. Dose-equivalent rate vs depth in tissue for galactic cosmicray proton spectra isotropically incident on spherical shell shields of various thicknesses (see Fig. 3.1).

7.2 THE VALIDITY OF USING ONLY UNATTENUATED PRIMARY PROTONS IN SHIELDING AGAINST INCIDENT GALACTIC COSMIC-RAY PROTONS

In Section 6.3.1 it was shown that in the case of incident Van Allen belt and solar-flare proton spectra reasonable estimates of the total dose rates or doses could be obtained by neglecting both the attenuation due to nuclear collisions and the secondary particles produced by nuclear collisions. To test this approximation, for incident galactic cosmic-ray protons the absorbed-dose rate and dose-equivalent rate at the center of the tissue sphere from unattenuated primary protons have been calculated for the cases considered in Figs. 7.3 and 7.4. The details concerning these calculations are given in Appendix 4.

It can be seen from Figs. 7.3 and 7.4 that the absorbed-dose rate and dose-equivalent rate obtained using unattenuated primary protons only are substantially less than the total absorbed-dose rate and dose-equivalent rate. Thus, in the case of incident galactic cosmic-ray protons reliable estimates of the absorbed-dose rate and dose-equivalent rate cannot be obtained on the basis of the unattenuated primary-proton flux.

Appendix 1

THE SOLUTION TO THE PRIMARY-PARTICLE TRANSPORT EQUATION

The solution to the primary-particle transport equation was given in Eqs. 3.6 and 3.7 of Chapter 3. In this appendix a derivation of this solution is presented.

The transport equation to be solved is that given as Eq. 3.5 of Chapter 3. After multiplying through by $S_{S_j}(E)$, the equation is

$$\frac{\partial [S_{Sj}(E) \phi_{j}(E,r)]}{\partial r} = S_{Sj}(E) \frac{\partial [S_{Sj}(E) \phi_{j}(E,r)]}{\partial E}$$

$$= S_{Sj}(E) \frac{\partial [S_{Sj}(E) \phi_{j}(E,r)]}{\partial E} , \qquad (A1.1)$$

where the symbol $\frac{\partial}{\partial x}$ indicates that the partial derivative with respect to x is to be taken with y held fixed. To solve the equation, it is convenient to change the variable from E to E, where E, is defined as a function of E and r through the equation

$$\int_{E}^{E_{j}} \frac{dE'}{S_{S_{j}}(E')} = r . \qquad (A1.2)$$

By the usual rules of differentiation,

$$\frac{\partial}{\partial \mathbf{r}} \Big|_{\mathbf{E}_{\mathbf{j}}} = \frac{\partial}{\partial \mathbf{r}} \Big|_{\mathbf{E}} + \frac{\partial \mathbf{E}}{\partial \mathbf{r}} \Big|_{\mathbf{E}_{\mathbf{j}}} \frac{\partial}{\partial \mathbf{E}} \Big|_{\mathbf{r}} , \qquad (A1.3)$$

and from Eq. Al. 2

$$\frac{\partial}{\partial r} \left[\int_{E}^{E_{j}} \frac{dE'}{S_{Sj}(E')} \right]_{E_{j}} = 1 , \qquad (A1.4)$$

SO

$$\frac{\partial E}{\partial r}\Big|_{E_{j}} = -S_{Sj}(E) \tag{A1.5}$$

and

$$\frac{\partial}{\partial \mathbf{r}}\Big|_{\mathbf{E}_{\mathbf{j}}} = \frac{\partial}{\partial \mathbf{r}}\Big|_{\mathbf{E}} - \mathbf{S}_{\mathbf{S}\mathbf{j}}(\mathbf{E}) \left. \frac{\partial}{\partial \mathbf{E}} \right|_{\mathbf{r}} . \tag{A1.6}$$

Using Eq. Al.6, Eq. Al.1 becomes

$$\frac{\partial \left[\chi_{Sj}(E_{j},r)\right]}{\partial r} \bigg|_{E_{j}} - \sigma_{Sj}[E(E_{j},r)] \chi_{Sj}(E_{j},r) = 0 , \qquad (A1.7)$$

where

$$\chi_{Sj}(E_{j},r) = S_{Sj}[E(E_{j},r)] \Phi_{Sj}[E(E_{j},r),r]$$
 (A1.8)

Equation A1.7 may now be solved to give

$$\chi_{Sj}(E_j,r) = \chi_{Sj}(E_j,0) \exp \left\{ -\int_0^r \sigma_{Sj}[E(E_j,r)] dr \right\} . \tag{A1.9}$$

By using Eq. Al.8 and noting from Eq. Al.2 that $E_j = E$ when r = 0, Eq. Al.9 may be written

$$S_{Sj}(E) \phi_{j}(E,r) = S_{Sj}(E_{j}) \phi_{j}(E_{j},0) \exp \left\{ - \int_{0}^{r} \sigma[E(E_{j},r)] dr \right\},$$
 (A1.10)

where E must still be determined in terms of E and r from Eq. Al.2. To put the exponential in Eq. Al.10 in a more convenient form, note that

$$dE = \frac{\partial E}{\partial r} \Big|_{E_{j}} dr , \qquad (A1.11)$$

so from Eq. Al.5

$$dr = \frac{dE}{S_{Sj}(E)}$$
 (A1.12)

and then

$$\int_{0}^{r} \sigma_{Sj}[E(E_{j},r)] dr = \int_{E}^{E_{j}} \frac{\sigma(E')}{S_{Sj}(E')} dE' , \qquad (A1.13)$$

so Eq. Al.10 becomes

$$\phi_{j}(E,r) = \phi_{jo}(E_{j}) \frac{S_{Sj}(E_{j})}{S_{Sj}(E)} \exp \left\{ - \int_{E}^{E_{j}} \frac{\sigma_{Sj}(E')}{S_{Sj}(E')} dE' \right\} ,$$
(A1.14)

where

$$\phi_{jo}(E_j) = \phi_j(E_j, 0)$$
 (A1.15)

Equation Al.14, together with Eq. Al.2, is the solution to the primary-particle transport equation that was used in Chapter 3.

Appendix 2

NUMERICAL DATA ON ABSORBED DOSE AND DOSE EQUIVALENT FROM PRIMARY PARTICLES

In this appendix the absorbed-dose rate or absorbed dose and the dose-equivalent rate or dose equivalent as a function of shield thickness are presented for a variety of incident Van Allen belt and solar-flare spectra. The incident Van Allen belt spectra used in the calculations correspond to circular orbits through the belt and are shown in Figs. 2.8 to 2.12. The incident solar-flare spectra were assumed to be exponential in rigidity and for both protons and alpha particles were normalized to 10° particles cm⁻² between 30 and 3000 MeV. Results are presented for characteristic rigidities of 50, 75, 100, 125, 150, 175, and 200 MV (see Fig. 2.12).

All of the results were obtained with the primary-particle-transport code TRAPP for the geometry shown in Fig. 3.1. The calculated values give the various doses at the center of the spherical shell shield and are independent of the radius of the vacuum gap as shown in Fig. 3.1. In all cases, the incident spectra were assumed to be isotropically incident on the shield. For each incident spectrum, calculated values are given with radii, r_T , of 0 and 15 g cm⁻². The cross-section values used are those shown in Figs. 4.10 and 4.11, and the stopping powers used are those shown in Fig. 4.1 and by the solid curves in Fig. 4.3. Results are given for shields of aluminum, polyethylene, and copper and for shield thicknesses, r_S , from 2 to 100 g cm⁻².

Table A2.1 lists the tables containing results for incident Van Allen belt protons. Tables A2.2 and A2.3 list the tables containing results for incident solar-flare protons and alpha particles, respectively.

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TABLE A2.1
List of Tables for Incident Van Allen Belt Protons

Table	Orbital Altitude (nautical miles)	Orbital Inclination (deg)	Shield Material	Dose Rate rad or rem day	Page
A2.4	240	30	Aluminum	Absorbed	227
A2.5	240	30	Aluminum	Equivalent	228
A2.6	240	30	Polyethylene	Absorbed	229
A2.7	240	30	Polyethylene	Equivalent	230
A2.8	240	30	Copper	Absorbed	231
A2.9	240	30	Copper	Equivalent	232.
A2.10	240	60	Aluminum	Absorbed	233
A2.11	240	60	Aluminum	Equivalent	234
A2.12	240	60	Polyethylene	Absorbed	235
A2.13	240	60	Polyethylene	Equivalent	236
A2.14	240	60	Copper	Absorbed	237
A2.15	240	60	Copper	Equivalent	238
A2.16	240	90	Aluminum	Absorbed	239
A2.17	240	90	Aluminum	Equivalent	240
A2.18	240	90	Polyethylene	Absorbed	241
A2.19	240	90	Polyethylene	Equivalent	242
A2.20	240	90	Copper	Absorbed	243
A2.21	240	90	Copper	Equivalent	244
A2.22	1500	0	Aluminum	Absorbed	245
A2.23	1500	0	Aluminum	Equivalent	246
A2.24	1500	0	Polyethylene	Absorbed	247
A2.25	1500	0	Polyethylene	Equivalent	248
A2.26	1500	0	Copper	Absorbed	249
A2.27	1500	0	Copper	Equivalent	250
A2.28	1500	30	Aluminum	Absorbed	251
A2.29	1500	30	Aluminum	Equivalent	252
A2.30	1500	30	Polyethylene	Absorbed	253
A2.31	1500	30	Polyethylene	Equivalent	254
A2.32	1500	30	Copper	Absorbed	255
A2.33	1500	30	Copper	Equivalent	256
A2.34	1500	60	Aluminum	Absorbed	257
A2.35	1500	60	Aluminum	Equivalent	258
A2.36	1500	60	Polyethylene	Absorbed	259
A2.37	1500	60	Polyethylene	Equivalent	260
A2.38	1500	60	Copper	Absorbed	261
A2.39	1500	60	Copper	Equivalent	262
A2.40	1500	90	Aluminum	Absorbed	²⁶²
A2.41	1500	90	Aluminum	Equivalent	264
A2.42	1500	90	Polyethylene	Absorbed	265
A2.43	1500	90	Polyethylene	Equivalent	266
A2.44	1500	90	Copper	Absorbed	267
A2.45	1500	90	Copper	Equivalent	268
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TABLE A2.1 (cont'd)
List of Tables for Incident Van Allen Belt Protons

	Orbital Altitude	Orbital		Dose Rate	•
	(nautical	Inclination	Shield	rad or rem	
Table	miles)	(deg)	Material	day	Page
A2.46	3000	0	Aluminum	Absorbed	269
A2.47	3000	0	Aluminum	Equivalent	270
A2.48	3000	0	Polyethylene	Absorbed	271
A2.49	3000	0	Polyethylene	Equivalent	272
A2.50	3000	0	Copper	Absorbed	273
A2.51	3000	0	Copper	Equivalent	274
A2.52	3000	30	Aluminum	Absorbed	275
A2.53	3000	30	Aluminum	Equivalent	276
A2.54	3000	30	Polyethylene	Absorbed	277
A2.55	3000	30	Polyethylene	Equivalent	278
A2.56	3000	· 30	Copper	Absorbed	279
A2.57	3000	¥ *	Copper	Equivalent	280
A2.58	3000	60	Aluminum	Absorbed	281
A2.59	3000	60	Aluminum	Equivalent	282
A2.60	3 000	60	Polyethylene	Absorbed	283
A2.61	3000	60	Polyethylene	Equivalent	284
A2.62	3000	60	Copper	Absorbed	285
A2.63	3000	60	Copper	Equivalent	286
A2.64	3000	90	Aluminum	Absorbed	287
A2.65	3000	90	Aluminum	Equivalent	288
A2.66	3000	90	Polyethylene	Absorbed	289
A2.67	3000	90	Polyethylene	Equivalent	290
A2.68	3000	90	Copper	Absorbed	291
A2.69	3000	90	Copper	Equivalent	292
A2.70	4500	0	Aluminum	Absorbed	293
A2.71	4500	0	Aluminum	Equivalent	294
A2.72	4500	0	Polyethylene	Absorbed	295
A2.73	4500	0	Polyethylene	Equivalent	296
A2.74	4500	0	Copper	Absorbed	297
A2.75	4500	0	Copper	Equivalent	298
A2.76	4500	30	Aluminum	Absorbed	299
A2.77	4500	30	Aluminum	Equivalent	300
A2.78	4500	30	Polyethylene	Absorbed	301
A2.79	4500	30	Polyethylene	Equivalent	302
A2.80	4500	30	Copper	Absorbed	303
A2.81	4500	30	Copper	Equivalent	304
A2.82	4500	60	Aluminum	Absorbed	305
A2.83	4500	60	Aluminum	Equivalent	306
A2.84	4500	60	Polyethylene	Absorbed	307
A2.85	4500	60	Polyethylene	Equivalent	308
A2.86	4500	60	Copper	Absorbed	309
A2.87	4500	60	Copper	Equivalent	310

TABLE A2.1 (cont'd)
List of Tables for Incident Van Allen Belt Protons

	Orbital Altitude (nautical	Orbital Inclination	Shield	Dose Rate	
Table	miles)	(deg)	Material	day	Page
A2.88	4500	90	Aluminum	Absorbed	311
A2.89	4500	90	Aluminum	Equivalent	312
A2.90	4500	90	Polyethylene	Absorbed	31.3
A2.91	4500	90	Polyethylene	Equivalent	314
A2.92	4500	90	Copper	Absorbed	315
A2.93	4500	90	Copper	Equivalent	316
A2.94	6000	0	Aluminum	Absorbed	317
A2.95	6000	0	Aluminum	Equivalent	318
A2.96	6000	0	Polyethylene	Absorbed	319
A2.97	6000	0	Polyethylene	Equivalent	320
A2.98	6000	0	Copper	Absorbed	321
A2.99	6000	0	Copper	Equivalent	322
A2.100	6000	30	Aluminum	Absorbed	323
A2.101	6000	30	Aluminum	Equivalent	324
A2.102	6000	30	Polyethylene	Absorbed	325
A2.103	6000	30	Polyethylene	Equivalent	326
A2.104	6000	30	Copper	Absorbed	327
A2.105	6000	30	Copper	Equivalent	328
A2.106	6000	60	Aluminum	Absorbed	329
A2.107	6000	60	Aluminum	Equivalent	330
A2.108	6000	60	Polyethylene	Absorbed	331
A2.109	60 00	60	Polyethylene	Equivalent	332
A2.110	6000	60	Copper	Absorbed	333
A2.111	50 00	60	Copper	Equivalent	334
A2.112	6000	90	Aluminum	Absorbed	335
A2.113	60 00	90	Aluminum	Equivalent	336
A2.114	6000	90	Polyethylene	Absorbed	337
A2.115	6000	90	Polyethylene	Equivalent	338
A2.116	6000	90	Copper	Absorbed	339
A2.117	6000	90	Copper	Equivalent	340

TABLE A2.2
List of Tables for Incident Solar-Flare Protons

	Characteristic			
m	Rigidity	Shield	Dose	
Table	(MV)	Material	(rad or rem)	Page
A2.118	50	Aluminum	Absorbed	341
A2.119	50	Aluminum	Equivalent	342
A2.120	50	Polyethylene	Absorbed	343
A2.121	50	Polyethylene	Equivalent	344
A2.122	50	Copper	Absorbed	345
A2.123	50	Copper	Equivalent	346
A2.124	75	Aluminum	Absorbed	347
A2.125	75	Aluminum	Equivalent	348
A2.126	75	Polyethylene	Absorbed	349
A2.127	75	Polyethylene	Equivalent	350
A2.128	75	Copper	Absorbed	351
A2.129	75	Copper	Equivalent	352
A2.130	100	Aluminum	Absorbed	352
A2.131	100	Aluminum	Equivalent	354
A2.132	100	Polyethylene	Absorbed	355
A2.133	100	Polyethylene	Equivalent	356
A2.134	100	Copper	Absorbed	357
A2.135	100	Copper	Equivalent	358
A2.136	125	Aluminum	Absorbed	359
A2.137	125	Aluminum	Equivalent	360
A2.138	125	Polyethylene	Absorbed	361
A2.139	125	Polyethylene	Equivalent	362
A2.140	125	Copper	Absorbed	363
A2.141	125	Copper	Equivalent	364
A2.142	150	Aluminum	Absorbed	365
A2.143	150	Aluminum	Equivalent	366
A2.144	150	Polyethylene	Absorbed	367
A2.145	150	Polyethylene	Equivalent	368
A2.146	150	Copper	Absorbed	369
A2.147	150	Copper	Equivalent	370
A2.148	175	Aluminum	Absorbed	371
A2.149	175	Aluminum	Equivalent	372
A2.150	175	Polyethylene	Absorbed	372 373
A2.151	175	Polyethylene	Equivalent	374
A2.152	175	Copper	Absorbed	375
A2.153	175	Copper	Equivalent	376
A2.154	200	Aluminum	Absorbed	377
A2.155	200	Aluminum	Equivalent	378
12.156	200	Polyethylene	Absorbed	379
A2.157	200	Polyethylene	Equivalent	380
12.158	200	Copper	Absorbed	381
12.159	200	Copper	Equivalent	382

TABLE A2.3
List of Tables for Incident Solar-Flare Alpha Particles

	Characteristic	Ch ())		
Table	Rigidity (MV)	Shield Material	Dose (rad or rem)	Dana
	(,	riacer rar	(rad or rem)	Page
A2.160	50	Aluminum	Absorbed	38 3
A2.161	50	Aluminum	Equivalent	384
A2.162	50	Polyethylene	Absorbed	385
A2.163	50	Polyethylene	Equivalent	386
A2.164	50	Copper	Absorbed	387
A2.165	50	Copper	Equivalent	388
A2.166	75	Aluminum	Absorbed	389
A2.167	75	Aluminum	Equivalent	390
A2.168	75	Polyethylene	Absorbed	391
A2.169	75	Polyethylene	Equivalent	392
A2.170	75	Copper	Absorbed	393
A2.171	75	Copper	Equivalent	394
A2.172	100	Aluminum	Absorbed	395
A2.173	100	Aluminum	Equivalent	396
A2.174	100	Polyethylene	Absorbed	397
A2.175	100	Polyethylene	Equivalent	398
A2.176	100	Copper	Absorbed	399
A2.177	100	Copper	Equivalent	400
A2.178	125	Aluminum	Absorbed	401
A2.179	125	Aluminum	Equivalent	402
A2.180	125	Polyethylene	Absorbed	403
A2.181	125	Polyethylene	Equivalent	404
A2.182	125	Copper	Absorbed	405
A2.183	125	Copper	Equivalent	406
A2.184	150	Aluminum	Absorbed	407
A2.185	150	Aluminum	Equivalent	408
A2.186	150	Polyethylene	Absorbed	409
A2.187	150	Polyethylene	Equivalent	410
A2.188	150	Copper	Absorbed	411
A2.189	150	Copper	Equivalent	412
A2.190	175	Aluminum	Absorbed	413
A2.191	175	Aluminum	Equivalent	414
A2.192	175	Polyethylene	Absorbed	415
A2.193	175	Polyethylene	Equivalent	416
A2.194	17 5	Copper	Absorbed	417
A2.195	175	Copper	Equivalent	418
A2.196	200	Aluminum	Absorbed	419
A2.197	200	Aluminum	Equivalent	420
A2.198	200	Polyethylene	Absorbed	421
A2.199	200	Polyethylene	Equivalent	422
A2.200	200	Copper	Absorbed	423
A2.201	200	Copper	Equivalent -	424

TABLE A2.4

PROTONS AS INCIDENT PARTICLES SHIELD HATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 MAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 3.0000 ABSORBED DOSE	000E 01 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CH2	R.T = 15.0 G/CH2	R.T = 0.0 G/CH2	R,T = 15.0 G/CH2
SHIELD	WITHOUT	WITHOUT	WITH	UITH
DEPTH	ATTENUATION	NCITAUNSTTA	ATTENUATION	MCITAUNSTIA
R.S (G/CH2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY
2.00	4.55E-01	6.45E-02	4.45E-01	
3.00	3.66E-01	6.08E-02	3.548-01	5.258-02 4.90E-02
5.00	2.63E-01	5.42E-02	2.492-01	4.292-02
7.00	2.04E-01	4.85E-02	1.898-01	3.772-02
10.00	1.50E-01	4.14E-02	1.352-01	3.145-02
15.00	9.92E-02	3.25E-02	8.51E-02	2.36E-02
20.00	7.07E-02	2.59E-02	5.79E-02	1.808-02
25.00	5.27E-02	2.10E-02	4.13E-02	1.395-02
30.00	4.05E-02	1.72E-02	3.03E-02	1.09E-02
35.00	3. 18E-02	1.42E-02	2.288-02	8.63E-03
40.00	2.54E-02	1.18E-02	1.74E-02	6.89E-03
45.00	2.06E-02	9.93E-03	1.35E-02	5.53E-03
50.00	1.69E-02	8.38E-03	1.06E-02	4.46E-03
60.00	1. 17E-02	6.07E-03	6.712-03	2.95E-03
70.00	8.27E-03	4.47E-03	4.35E-03	1.985-03
80.00	6.00E-03	3.33E-03	2.88E-03	1.352-03
90.00	4.42E-03	2.52E-03	1.94E-03	9.275-04
100.00	3.30E-03	1.92E-03	1.32E-03	6.422-04

TABLE A2.5

	A. SPECTRUM = 2.4	IELD HATERIAL ALUMIN 000000E 02 NAUFICAL 000E 01 DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE		
	R.T = 0.0 G/CH2	R.T = 15.0 G/CM2	$R_*P = 0.0 \text{ G/CM2}$	8.7 = 15.0 G/CH2	
SHIELD	WITHOUT	WITHOUT	WITH	算工学経	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	MOTTANUATION	
R, S (G/CH2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	RER YAG CO.1 REP	
2.00	6.35E-01	7.48E-02	6.22E-01	6.07E-02	***
3.00	4.93E-01	7.04E-02	4.77E-01	5.66E-02	QK:
5.00	3.42E-01	6.25E-02	3.23E-01	4.94 E-02	
7.00	2.59E-01	5.58E-02	2.40E-01	4.33E- 02	
10.00	1.86E-01	4.75E-02	1.67E-01	3.59 8-02	
15.00	1.20E-01	3.70E-02	1.03E-01	2.58E-02	
20.00	8.46E-02	2.94E-02	6.92E-02	2.03E-02	
25.00	6.24E-02	2.37E-02	4.88E-02	1.575-92	
30.00	4.75E-02	1.94E-02	3.56E-02	1.235-02	
35.00	3.71E-02	1.60E-02	2.66E-02	9.672-03	
40.00	2.95E-02	1.33E-02	2.02E-02	7.702-03	
45.00	2.38E-02	1.11E-02	1.56E-02	5.178- 93	
50.00	1.95E-02	9.36E-03	1.22E-02	4.97E-93	
60.00	1.34E-02	6.75E-03	7.67E-03	3.282-93	
70.00	9.43E-03	4.96E-03	4.95E-03	2.202-03	
80.00	6.81E-03	3.69E-03	3.27E-03	1.492-33	
90.00	5.00E-03	2.78E-03	2.19E-03	1.025-03	
100.00	3.72E-03	2.12E-03	1.49E-03	7.083-04	

PROTONS AS INCIDENT PARTICLES SHIELD NATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ARGLE OF V. A.	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	RATE	RATE	RATE	SARE
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	2,T = 0.0 6/332	R.T = 15.0 G/CH2
SHIELD	WITHOUT	WITHOUT	WITH	WIZH
DEPTH	ATTENUATION	NCITAUNSTEE	ATTENUATION	MCILYONALLT
R. S (G/CM2)	RAD	RAD	RAD	330
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	3.71E-01	6.17E-02	3.58E-01	5.00E-02
3.00	2.90E-01	5.70E-02	2.76E-01	4.56E-C2
5.0C	2.01E-01	4.90E-02	1.86E-01	3.83E-02
7.00	1.51E-01	4.25E-02	1.36E-01	3.24E-02
10.00	1.06E-01	3.47E-02	9.23E-02	2.56E-G2
15.00	6.66E-02	2.55E-02	5.45E-02	1.78E-02
20.00	4.53E-02	1.92E-02	3.50E-02	1.26E-02
25.00	3, 24E-02	1.48E-02	2.36E-02	9.19E-33
30.00	2.39E-02	1.16E-02	1.65E-02	6.79E-03
35.00	1.81E-02	9.14E-03	1.18E-02	5.07E-03
40.00	1.40E-02	7.31E-03	8.60E-03	3.82E-03
45.00	1. 10E-02	5.90E-03	6.36E-03	2.912-03
50.00	8.69E-03	4.79E-03	4.76E-03	2.238-03
60.00	5.63E-03	3.23%-03	2.74E-03	1.33E-03
70.00	3.75E-03	2.222-03	1.62E-03	8. 04E-04
80.00	2.57E-03	1.55E-03	9.77E-04	4.932-04
90.00	1.78E-03	1. 10E-03	5.96E-04	3.05E-04
100.00	1.26E-03	7.91E-04	3.68E-04	1.91E-04
	110 GUB-UJ	10 3 12 VY	ALMAN AL	李新峰李麟『蟹河

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A	. SPECTRUM = 3.0000	000E 01 DEGREES	n i i i i i i i i i i i i i i i i i i i		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	B.T = 0.0 G/382	R.T = 15.0 G/CH2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	AFTENUATION	
R,S (G/CM2)	REM	REM	REM	REN	
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	4.77E-01	7.15E-02	4.62E-01	5.77E-02	N
3.00	3.64E-01	6.59E-02	3.46E-01	5.26E-02	230
5.00	2.44E-01	5.64E-02	2.26E-01	4.39E-02	
7.00	1.80E+01	4.87E-02	1.62E-01	3.71E-02	
10.00	1.25E-01	3.96E-02	1. 08E-01	2.915-02	
15.00	7.69F-02	2.89E-02	6.28E-02	2.01E-02	
20.00	5.18E-02	2.17E-02	3.98E-02	1.425-02	
25.00	3.67E-02	1.66E-02	2.67E-02	1.03R-02	
30.00	2.70E-02	1.29E-02	1.852-02	7.582-03	
35.00	2.03E-02	1.02E-02	1.32E-02	5.64B-03	
40.00	1.56E-02	8.14E-03	9.588-03	, , , , , , , , , , , , , , , , , , , ,	
45.00	1. 22E-02	6.56E-03	7.07E-03	4.25E-03	
50.00	9.66E-03	5.32E-03	5.28E-03	3.23E-03	
60.00	6.23E-03	3.57E-03		2.47E-03	
70.00	4.14E-03	2.45E-03	3.032-03	1.47E-03	
80.00	2. 82E-03	1.71E-03	1.78E-03	8.87E-04	
90.00	1.96E-03		1.072-03	5.43E-04	
100.00	1.38E-03	1.21E-03	6.54E-04	3.36E-04	
10000	1. 305-03	8.68E-04	4.03E-04	2.10E-34	

TABLE A2.8

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	BATE	RATE	RATE	
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	R.T = 0.0 G/CH2	R.T = 15.0 G/CH2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R. S (G/CM2)	RAD	PAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	5.13E-01	6.56E-02	5.05E-01	5.36E-02	N
3.00	4.16E-01	6.23E-02	4.06E-01	5.06E-02	231
5.00	3.05E-01	5.64E-02	2.93E-01	4.51E-02	
7.00	2.40E-01	5.12E-02	2.26E-01	4.04B-02	
10.00	1.79E-01	4.46E-02	1.65E-01	3.45E-02	
15.00	1.21E-01	3.59E-02	1.08E-01	2.68E-02	
20.00	8.80E-02	2.94E-02	7.55E-02	2. 12E-02	
25.00	6.67E-02	2.43E-02	5.53E-02	1.69E-02	
30.00	5.21E-02	2.03E-02	4.17E-02	1. 36E-02	
35.00	4.15E-02	1.71E-02	3.212-02	1.11E-02	
40.00	3.37E-02	1.45E-02	2.51E-02	9.09E-03	
45.00	2.77E-02	1.24E-02	1.99E-02	7.50E-03	
50.00	2.30E-02	1.06E-02	1.60E-02	6.21E-03	
60.00	1.63E-02	7.90E-03	1.06E-02	4.32E-03	
70.00	1. 18 E-02	5.99E-03	7.16E-03	3.05E-03	
80.00	8.78E-03	4.59E-03	4.95E-03		
90.00	6.61E-03	3.55E-03	3.48E-03	2.185-03	
100.00	5.05E-03	2.77E-03		1.57E-03	
	21421-03	2.115-03	2.48E-03	1.14E-03	

PROTONS AS INC	IDENT PARTICLES SHIELD MATERIAL COPPER	
ALTITUDE OF V.	A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES	î
	SPECTRUM = 3.0000000E 01 DEGREES	

ANGLE OF V. A.	SPECTRUM = 3.0000	000E 01 DEGREES	14 th 45 45 45	
	DOSE EQUIVALENT		DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$	$R_T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R, S (G/CM2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	REN PER 1.00 DAY
2.00	7.61E-01	7.62E-02	7.50E-01	6.212-32
3.00	5.95E-01	7.22E-02	5.82E-01	5.852-02
5.00	4. 17E-01	6.51E-02	4.01E-01	5.202-02
7.00	3.20E-01	5.90E-02	3.02E-01	4.65E-02
10.00	2.32E-01	5.12E-02	2.15E-01	3.95E-02
15.00	1.53E-01	4.10E-02	1.37E-01	3.06E-02
20.00	1. 10E-01	3.34E-02	9.40E-02	2.40E-32
25.00	8.20E-02	2.75E-02	6.79E-02	1.91E-02
30.00	6.34E-02	2.29E-02	5.07E-02	1.54E-02
35.00	5.02E-02	1.93E-02	3.88E-02	1.25E-02
40.00	4.05E-02	1.63E-02	3.02E-02	1.02E-02
45.00	3.31E-02	1.39E-02	2.38E-02	8.39E-03
50.00	2.74E-02	1.19E-02	1.90E-02	6.942-03
60.00	1.92E-02	8.82E-03	1.25E-02	4.812-03
70.00	1.39E-02	6.66E-03	8.40E-03	3.392-03
80.00	1.03E-02	5.10E-03	5.79E-03	2.418-03
90.00	7.70E-03	3.93E-03	4.05E-03	1,743-03
100.00	5.87E-03	3.07E-03	2.88E-03	1.265-03

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	ABSORBED DOSE	OOOE O1 DEGREES ABSORBED DOSE	ABSORBED DOSE	18618080 0000	
			abounded boss	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	$R_{\star}T = 15.0 \text{ G/CH}_2$	R.T = 0.0 G/CH2	R.T = 15.0 G/CH2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	22.0	***	
	PER 1.00 DAY	PER 1.00 DAY	RAD PER 1.00 DAY	RAD	
2.00	2.68E-01	2.87E-02		PER 1.00 DAY	
3.00	2.09E-01	2.68E-02	2.62E-01	2.33E-02	233
5.00	1.44E-01	2.35E-02	2.02E-01	2.162-02	ធ
7.00	1.07E-01	2.07E-02	1.36E-01	1.86E-02	
10.00	7.51E-02	1.73E-02	9.92E-02	1.61E-02	
15.00	4.68E-02	1.32E-02	6.75E-02	1.31E-02	
20.00	3.18E-02		4.01E-02	9.54E-03	
25.00	2.27E-02	1.02E-02	2.60E-02	7.09E-03	
30.00	1.69E-02	8.07E-03	1.78E-02	5.35E-03	
35.00	1.28E-02	6.46E-03	1.26E-02	4.10E-03	
40.00	9.99E-03	5.24E-03	9.20E-03	3. 18E-03	
45.00	7.91E-03	4.28E-03	6.85E-03	2.49E-03	
50.00	6.34E-03	3.53E-03	5.18E-03	1.96E-03	
60.00		2.93E-03	3.98E-03	1.56E-03	
70.00	4.21E-03	2.06E-03	2.42E-03	1.00E-03	
80.00	2.89E-03	1.48E-03	1.52E-03	6.57E-04	
90.00	2.03E-03	1.08E-03	9.76E-04	4.37E-04	
	1.46E-03	7.97E-04	6.41E-04	2.94E-04	
100.00	1.07E-03	5.97E-04	4.26E-04	2.00E-04	

TABLE A2.11

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

		000000 01 DEGREES	BILES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CH2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CITAUN STT A	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM	REM	
2.00	3.83E-01	3.36E-02	PER 1.00 DAY	PER 1.00 DAY	
3.00	2.88E-01	3.13E-02	3.75E-01	2.72E-02	234
5.00	1.90E-01		2.79E-01	2.52E-02	4
7.00	1.39E-01	2.74E-02	1.80E-01	2.16E-02	
10.00	9.48E-02	2.41E-02	1.28E-01	1.87E-02	
15.00	_	2.01E-02	8.51E-02	1.52E-02	
	5.77E-02	1.52E-02	4.93E-02	1.09E-32	
20.00	3.85E-02	1.17E-02	3.15E-02	8.08E-03	
25.00	2.72E-02	9.20E-03	2.13E-02	6.08E-03	
30.00	2.00E-02	7.33E-03	1.50E-02	4.64E-03	
35.00	1.52E-02	5.92E-03	1.08E-02	3.59E-03	
40.00	1.17E-02	4.83E-03	8.01E-03	2.80E-03	
45.00	9.22E-03	3.97E-03	6.04E-03	2.20E-03	
50.00	7.36E-03	3.29E-03	4.6 E-03	1.75E-03	
60.00	4.86E-03	2.30E-03	2.78E-03	1. 12E-03	
70.00	3.32E-03	1.65E-03	1.74E-03	7.30E-04	
80.00	2.32E-03	1.20E-03	1.11E-03	4.85E-04	
90.00	1.66E-03	8.84E-04	7.28E-04	3.25E-04	
100.00	1.21E-03	6.61E-04	4.83E-04	2. 21E-04	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 6.0000	OOOE O1 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_{\bullet}T = 0.0 \text{ G/CM2}$	$R_eT = 15.0 \text{ G/CM}2$	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CH2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	2. 12E-01	2.73E-02	2.05E-01	2.20E-02	235
3.00	1.60E-01	2.49E-02	1.53E-01	1.99E-02	Çī
5.00	1.05E-01	2.10E-02	9.72E-02	1.64E-02	
7.00	7.57E-02	1.78E-02	6.82E-02	1.36E-02	
10.00	5.07E-02	1.42E-02	4.40E-02	1.05E-02	
15.00	2.97E-02	1.00E-02	2.43E-02	6.98E-03	
20.00	1.92E-02	7.32E-03	1.48E-02	4.82E-03	
25.00	1.31E+02	5.48E-03	9.56E-03	3.40E-03	
30.00	9.35E-03	4.17E-03	6.43E-03	2.45E-03	
35.00	6.86E-03	3.22E-03	4.46E-03	1.79E-03	
40.00	5.15E-03	2.53E-03	3.16E-03	1.32E-03	
45.00	3.93E-03	2.00E-03	2.28E-03	9.85E-04	
50.00	3.05E-03	1.60E-03	1.67E-03	7.42E-04	
60.00	1.90E-03	1.04E-03	9.26E-04	4.29E-04	
70.00	1.23E-03	6.99E-04	5.30E-04	2.53E-04	
80.00	8.15E-04	4.79E-04	3.10E-04	1.52E-04	
90.00	5.54E-04	3.32E-04	1.85E-04	9.24E-05	
100.00	3.82E-04	2.34E-04	1.12E-04	5.67E-05	
100.00	3.02E-04	4.345-04	14 125-07	3.015.03	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	$\bullet SPECTRUM = 6.0000$	000E 01 DEGREES		•
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	N CIT AUN STT A	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM PER 1.00 DAY	REM	REM	REM
2.00	2.79E-01	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
3.00	2.05E-01	3.19E-02	2.70E-01	2.57E-02
5.00	1.30E-01	2.91E-02	1.95E-01	2.32E-02
7.00	9. 18E-02	2.44E-02	1.20E-01	1.90E-02
10.00	6.04E-02	2.06E-02	8.25E-02	1.57E-02
15.00	3.47E-02	1.63E-02	5.22E-02	1.20E-02
20.00	2.21E-02	1.15E-02	2.83E-02	7.96E-03
25.00	1.50E-02	8.32E-03	1.70E-02	5.46E-03
30.00	1.06E-02	6.19E-03	1.09E-02	3.84E-03
35.00	7.75E-03	4.70E-03	7.28E-03	2.75E-03
40.00	5.79E-03	3.62E-03	5.02E+03	2.00E-03
45.00	4.41E-03	2.83E-03	3.55E-03	1.48E-03
50.00	3.41E-03	2.23E-03	2.55E-03	1.10E-03
60.00	2. 11E-03	1.78E-03	1.86E-03	8.26E-04
70.00	1.36E-03	1.16E-03	1.03E-03	4.75E-04
80.00	8.99E-04	7.74E-04	5.86E-04	2.80E-04
90.00	6.10E+04	5.28E-04	3.42E-04	1.68E-94
100.00	4.20E-04	3.66E-04	2.04E-04	1.02E-04
	44.2011.04	2.57E-04	1.23E-04	6.25E-05

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

	ABSORBED DOSE	ABSORBED D3SE	ABSORBED DOSE	ABSORBED DOSE	
				ADSONDED DOSE	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM} 2$	$R_T = 15.0 \text{ G/CM}^2$	R,T = 0.0 G/CH2	R,T = 15.0 G/CM2	•
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	3.06E-01	2.92E-02	3,02E-01	2.38E-02	2
3.00	2.42E-01	2.76E-02	2.36E-01	2.385-02 2.23E-02	237
5.00	1.69E-01	2.46E-02	1.63E-01	1.96E-02	
7.00	1.29E-01	2.20E-02	1.21E-01	1.74E-02	
10.00	9.18E-02	1.88E-02	8.47E-02	1.45E-02	
15.00	5.87E-02	1.48E-02	5.22E-02	1. 10E-02	
20.00	4.07E-02	1.18E-02	3.49E-02	8.47E-03	
25.00	2.97E-02	9.51E-03	2.46E-02	6.61E-03	
30.00	2.24E-02	7.78E-03	1.79E-02	5. 23E-03	
35.00	1.73E-02	6.42E-03	1.34E-02	4.17E-03	
40.00	1.37E-02	5.35E-03	1.02E-02	3.36E-03	
45.00	1.10E-02	4.49E-03	7.90E-03	2. 72E- 03	
50.00	8.92E-03	3.79E-03	6.20E-03	2.22E-03	
60.00	6.07E-03	2.75E-03	3.94E-03	1.50E-03	
70.00	4.27E-03	2.03E-03	2.58E-03	1.03E-03	
80.00	3.08E-03	1.52E-03	1.74E-03	7. 22E-04	
90.00	2.26E-03	1.16E-03	1.19E-03	5. 11E-04	
100.00	1.68E-03	8.86E-04	8.27E~04	3.65E-04	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

·	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}^2$	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R, S (G/CM2)	REM	REM	REM	REM
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	4.67E-01	3.43E-02	4.61E-01	2.79E-02
3.00	3.55E-01	3.23E-02	3.47E-01	2.61E-02
5.00	2.37E-01	2.87E-02	2.28E-01	2.29E-02
7.00	1.75E-01	2.57E-02	1.66E-01	2.02E-02
10.00	1. 22E-01	2.18E-02	1.12E-01	1.68E-02
15.00	7.57E-02	1.70E-02	6.73E-02	1.27E-02
20.00	5.15E-02	1.35E-02	4.42E-02	- -
25.00	3.70E-02	1.09E-02	3.07E-02	9.69E-03
30.00	2.77E-02	8.86E-03	2.21E-02	7.54E-03
35.00	2.12E-02	7.29E-03	1.64E-02	5.93E-03
40.00	1.66E-02	6.06E-03	1.24E-02	4.72E-03
45.00	1.33E-02	5.07E-03	9.54E-03	3.79E-03
50.00	1.07E-02	4.27E-03	7.45E-03	3.06E-03
60.00	7.24E-03	3.09E-03		2.49E-03
70.00	5.06E-03	2.27E-03	4.69E-03	1.68E-03
80.00	3.62E-03		3.06E-03	1.15E-03
90.00	2.65E-03	1.70E-03	2.04E-03	8.03E-04
100.00	1.97E-03	1.29E-03	1.39E-03	5.68E-04
	1.7/2-03	9.84E-04	9.65E-04	4.04E-04

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000F 01 DECREES

ARGLE OF V. A.		0000E 01 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CH2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNSTTA	ATTENUATION	ATTENUATION	
R,S (G/CH2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	2.32E-01	2.86E-02	2.27E-01	2.33E-02	
3.00	1.83E-01	2.69E-02	1.77E-01	2. 33E-02 2. 17E-02	239
5.00	1.29E-01	2.38E-02	1. 22E-01		•
7.00	9.78E-02	2. 12E-02	9.05E-02	1.88E-02	
10.00	7.01E-02	1.79E-02	· · · · · · · · · · · · · · · · · · ·	1.65E-02	
15.00	4.52E-02	1.39E-02	6.31E-02	1.36E-02	
20.00	3.15E-02	1.09E-02	3.87E-02	1.01E-02	
25.00	2.31E-02	8.76E-03	2.58E-02	7.59E-03	
30.00	1.75E-02		1.81E-02	5.81E-03	
35.00	1. 36E-02	7.11E-03	1.31E-02	4.51E-03	
40.00	1.07E-02	5.82E-03	9.71E-03	3.54E-03	
45.00	8.60E-03	4.81E-03	7.35E-03	2.80E-03	
50.00		4.01E-03	5.64E-03	2.23E-03	
60.00	6.98E-03	3.36E-03	4.38E-03	1.79E-03	
	4.74E-03	2.40E-03	2.72E-03	1.17E-03	
70.00	3.32E-03	1.75E-03	1.74E-03	7.77E-04	
80.00	2.37E-03	1.29E-03	1.14E-03	5.23E-04	
90.00	1.73E-03	9.67E-04	7.59E-04	3.562-04	
100.00	1. 28E-03	7.32E-04	5.11E-04	2. 45E-04	

PROTONS AS	INCIDENT	PARTICLES	SHTELD !	ATERIAL	ALUMINUM
ALTITUDE OF	F V. A. S	PECTRUM =	2.4000000	E 02 NAU	TICAL MILES
ANGLE OF V.	A. SPEC	TRUM = 9.	000000E 0	1 DEGREE	2S

ANGLE OF V. A.	SPECTRUM = 9.0000 DOSE EQUIVALENT	OOOE O1 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}^2$	$R_T = 15.0 \text{ G/CM}^2$
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	N CITAUNATI A	ATTENUATION	ATTENUATION
R, S (G/CH2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	REM
2.00	3.28E-01	3.34E-02	3.21E~01	PER 1.00 DAY
3.00	2.50E-01	3.13E-02	2.42E-01	2.71E-02
5.00	1.68E-01	2.76E-02	1.59E-01	2.51E-02 2.18E-02
7.00	1.25E-01	2.45E-02	1. 16E-01	· · · · · · · · · · · · · · · · · · ·
10.00	8.78E-02	2.06E-02	7.88E-02	1.90E-02 1.56E-02
15.00	5.52E-02	1.59E-02	4.73E-02	1.15E-02
20.00	3.79E-02	1.25E-02	3.10E-02	8.61E-03
25.00	2.75E-02	9.93E-03	2.15E-02	6.58E-03
30.00	2.06E-02	8.03E-03	1.54E-02	5.09E-03
35.00	1.59E-02	6.56E-03	1.14E-02	3.98E-03
40.00	1.25E-02	5.41E-03	8.55E-03	3.14E-03
45.00	9.98E-03	4.50E-03	6.53E-03	2.50E-03
50.00	8.08E-03	3.76E-03	5.06E-03	2.00E-03
60.00	5.45E-03	2.68E-03	3.12E-03	1.30E-03
70.00	3.79E-03	1.95E-03	1.99E-03	8.62E-04
80.00	2.70E-03	1.43E-03	1.30E-03	5.79E-04
90.00	1.96E-03	1.07E-03	8.60E-04	3.94E-04
100.00	1.45E-03	8.08E-04	5.77E-04	2.71E-04

240

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. 1	A. SPECTRUM = 9.000	0000E 01 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.86E-01	2.73E-02	1.80E-01	2.21E-02	Ņ
3.00	1.43E-01	2.51E-02	1.36E-01	2.01E-02	241
5.00	9.60E-02	2.14E-02	8.88E-02	1.67E-02	
7.00	7.07E-02	1.84E-02	6.37E-02	1.40E-02	
10.00	4.87E-02	1.49E-02	4.22E-02	1.10E-02	
15.00	2.96E-02	1.07E-02	2.42E-02	7.49E-03	
20.00	1.97E-02	7.99E-03	1.52E-02	5. 26E-Q3	
25.00	1.38E-02	6.07E-03	1.01E-02	3.78E-03	
30.00	1.01E-02	4.70E-03	6.92E-03	2.76E-03	
35.00	7.52E-03	3.68E-03	4.89E-03	2.76E-03	
40.00	5.73E-03	2.91E-03	3.52E-03	_	
45.00	4.45E-03	2.33E-03	2.58E-03	1.52E-03	
50.00	3.49E-03	1.88E-03	·	1. 15E-03	
60.00	2. 22E-03	1.25E-03	1.91E-03	8.75E-04	
70.00	1.46E-03	8.52E-04	1.08E-03	5.14E-04	
80.00	9.87E-04		6.31E-04	3.08E-04	
90.00	6.79E-04	5.90E-04	3.76E-04	1.87E-04	
160.00		4.14E-04	2.27E-04	1.15E-04	
100400	4.74E-04	2.95E-04	1.39E-04	7.14E-05	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ARGLE OF V. A.	DOSE EQUIVALENT	000E 01 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}^2$	$R_T = 0.0 \text{ G/CM}_2$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AU N STT A	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	**	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	REM	
2.00	2.42E-01	3.18E-02	2.34E-01	PER 1.00 DAY	
3.00	1.81E-01	2.92E-02		2.57E-02	242
5.00	1.18E-01	2.47E-02	1.72E-01 1.09E-01	2.33E-02	2
7.00	8.51E-02	2.12E-02		1.93E-02	
10.00	5.75E-02	1.70E-02	7.65E-02	1.61E-02	
15.00	3.44E-02	1.22E-02	4.98E-02	1.25E-02	
20.00	2.26E-02	9.05E-03	2.80E-02	8.49E-03	
25.00	1.57E-02		1.74E-02	5.93E-03	
30.00	1.14E-02	6.84E-03	1.14E-02	4.24E-03	
35.00	8.46E-03	5.27E-03	7.80E-03	3.09E-03	
40.00	6.43E-03	4.12E-03	5.48E-03	2.28E-03	
45.00	4.97E-03	3.25E-03	3.94E-03	1.70E-03	
50.00	3.89E-03	2.60E-03	2.87E-03	1.28E-03	
60.00	· · · — - -	2.09E-03	2.13E-03	9.71E-04	
70.00	2.47E-03	1.39E-03	1.20E-03	5.69E-04	
	1.62E-03	9.41E-04	6.96E-04	3.41E-04	
80.00	1.09E-03	6.50E-04	4.14E-04	2.06E-04	
90.00	7.47E-04	4.56E-04	2.50E-04	1.27E-04	
100.00	5.20E-04	3.24E-04	1.53E-04	7.85E-05	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 9.000(ABSORBED DOSE	000E 01 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	•				
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM}^2$	R.T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	$R_T = 15.0 \text{ G/CM}^2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATFENUATION	
R.S (G/CH2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	2.63E-01	2.92E-02	2.59E-01	2.38E-02	2
3.00	2.10E-01	2.76E-02	2.05E-01	2.24E-02	243
5.00	1.50E-01	2.48E-02	1.44E-01	1.98E-02	
7.00	1.16E-01	2.24E-02	1.10E-01	1.77E-02	
10.00	8.47E-02	1.94E-02	7.82E-02	1.50E-02	
15.00	5.58E-02	1.54E-02	4.97E-02	1.15E-02	
20.00	3.97E-02	1.25E-02	3.41E-02	8.99E-03	
25.00	2.96E-02	1.02E-02	2.45E-02	7.11E-03	
30.00	2.28E-02	8.46E-03	1.82E-02	5.69E-03	
35.00	1.79E-02	7.07E-03	1.39E-02	4.59E-03	
40.00	1.44E-02	5.95E-03	1.07E-02	3.73E-03	
45.00	1.17E-02	5.04E-03	8.43E-03	3.05E-03	
50.00	9.63E-03	4.29E-03	6.70E-03	2.51E-03	
60.00	6.71E-03	3.16E-03	4.35E-03	1.73E-03	
70.00	4.81E-03	2.37E-03	2.91E-03	1.21E-03	
80.00	3.52E-03	1.80E-03	1.99E-03	8.54E-04	
90.00	2.62E-03	1.38E-03	1.38E-03	6.10E-04	
100.00	1.99E-03	1.07E-03	9.74E-04	4.40E-04	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 2.4000000E 02 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 9.0000 DOSE EQUIVALENT	OOOE 01 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}^2$	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	3.97E-01	3.40E-02	3.92E-01	2.77E-02	Ŋ
3.00	3.05E+01	3.21E-02	2.98E-01	2.60E-02	244
5.00	2.08E-01	2.88E-02	2.00E-01	2.30E-02	
7.00	1.56E-01	2.59E-02	1.48E-01	2.04E-02	
10.00	1. 11E-01	2.23E-02	1.03E-01	1.72E-02	
15.00	7.13E-02	1.77E-02	6.34E-02	1.32E-02	
20.00	4.98E-02	1.42E-02	4.28E-02	1.02E-02	
25.00	3.67E-02	1.16E-02	3.04E-02	8.07E-03	
30.00	2.79E-02	9.59E-03	2.23E-02	6.43E-03	
35.00	2.18E-02	7.99E-03	1.68E-02	5.18E-03	
40.00	1.74E-02	6.71E-03	1.30E-02	4.20E-03	
45.00	1.41E-02	5.67E-03	1.01E-02	3.43E-03	
50.00	1.15E-02	4.82E-03	8.00E-03	2.81E-03	
60.00	7.96E-03	3.54E-03	5.16E-03	1.93E-03	
70.00	5.67E-03	2.64E-03	3.43E-03	1.34E-03	
80.00	4.14E-03	2.00E-03	2.33E-03	9.48E-04	
90.00	3.07E-03	1.53E-03	1.61E-03	6.76E-04	
100.00	2.31E-03	1.18E-03	1. 13E-03	4.87E-04	

ALTITUDE OF V.	. A. SPECTRUM = 1.5	HIELD MATERIAL ALUMII 5000000E 03 NAUTICAL			
ANGLE OF V. A.		DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CH2	$R_T = 0.0 \text{ G/CM}_2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION	
R, S (G/CH2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	2.20E 02	5.32E 01	2.16E 02	4.34E 01	2
3.00	1.89E 02	5.08E 01	1.83E 02	4.11E 01	245
5.00	1.50E 02	4.66E 01	1.42E 02	3.70E 01	
7.00	1.25E 02	4.28E 01	1.16E 02	3.34E 01	
10.00	9.98E 01	3.79E 01	8.99E 01	2.88E 01	
15.00	7.37E 01	3.13E 01	6.33E 01	2.28E 01	
20.00	5.71E 01	2.62E 01	4.69E 01	1.82E 01	
25.00	4.57E 01	2.22E 01	3.58E 01	1.47E 01	
30.00	3.72E 01	1.89E 01	2.80E 01	1.20E 01	
35.00	3.08E 01	1.62E 01	2.22E 01	9.86E 00	
40.00	2.59E 01	1.40E 01	1.78E 01	8.13E Q0	
45.00	2.19E 01	1.21E 01	1.44E 01	6.74E 00	
50.00	1.87E 01	1.05E 01	1.17E 01	5.61E 00	
60.00	1.38E 01	8.08E 00	7.95E 00	3.93E 00	
70.00	1.04E 01	6.26E 00	5.49E 00	2.78E 00	
80.00	8.01E 00	4.90B 00	3.85E 00	1.98E 00	
90.00	6.21E 00	3.88E 00	2.72E 00	1.43E 00	
100.00	4.86E 00	3.08E 00	1.94E 00	1.03È 00	

TABLE A2.23

PROTONS AS INC	CIDENT PARTICLES	SHIELD MATERIAL ALUMINUM
ALTITUDE OF V.	A. SPECTRUM =	1.5000000E 03 NAUFICAL MILES
ANGLE OF V. A.	SPECTRUM = 0.	0 DEGREES

ANGLE OF V. A.	• SPECTRUM = 0.0	DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CH2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNATION	
R,S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	2.90E 02	6.04E 01	2.84E 02	4.92E 01	
3.00	2.42E 02	5.77E 01	2.34E 02	4.65E 01	246
5.00	1.86E 02	5.27E 01	1.76E 02		
7.00	1.52E 02	4.83E 01	1.41E 02	4.17E 01	
10.00	1.20E 02	4.27E 01	1.08E 02	3.76E 01	
15.00	8.69E 01	3.51E 01	7.46E 01	3.23E 01	
20.00	6.67E 01	2.93E 01		2.55E 01	
25.00	5.29E 01	2.47E 01	5.46E 01	2.03E 01	
30.00	4.29E 01	2.10E 01	4.14E 01	1.64E 01	
35.00	3.53E 01	1.80E 01	3.21E 01	1.33E 01	
40.00	2.95E 01	1.55E 01	2.53E 01	1.09E 01	
45.00	2.49E 01		2.02E 01	8.98E 00	
50.00	2.12E 01	1.34E 01	1.63E 01	7.43E 00	
60.00	1.56E 01	1.16E 01	1.33E 01	6.18E 00	
70.00		8.89E 00	8.95E 00	4.32E 00	
	1.17E 01	6.88E 00	6.16E 00	3.05E 00	
80.00	8.98E 00	5.37E 00	4.31E 00	2.17E 00	
90.00	6.95E 00	4.24E 00	3.04E 00	1.56E 00	
100.00	5.43E 00	3.37E 00	2.17E 00	1.13E 00	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE

	A. SPECTRUM = 1.	5000000E 03 NAUTICAL DEGREES ABSORBED DOSE		ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	EAD	RAD	RAD PER 1.00 DAY	RAD PER 1.00 DAY	
2.00	PER 1.00 DAY 1.90E 02	PER 1.00 DAY 5.15E 01	1.84E 02	4.18E 01	N
3.00	1.60E 02	4.84E 01	1.52E 02	3.88E 01	247
5.00	1.00E 02	4.31E 01	1.14E 02	3.38E 01	
7.00	9.99E 01	3.86E 01	9.04E 01	2.95E 01	
10.00	7.73E 01	3.30E 01	6.74E 01	2.44E 01	
15.00	5.45E 01	2.59E 01	4.47E 01	1.81E 01	
20.00	4.06E 01	2.07E 01	3.14E 01	1.36E 01	
25.00	3.12E 01	1.67E 01	2.28E 01	1.04E 01	
30.00	2.46E 01	1.37E 01	1.70E 01	8.04E 00	
35.00	1.97E 01	1.13E 01	1.28E 01	6.27E 00	
40.00	1.60E 01	9.42E 00	9.83E 00	4.92E GO	
45.00	1.31E 01	7.89E 00	7.61E 00	3.89E 00	
50.00	1.09E 01	6.64E 00	5.95E 00	3.08E 00	
60.00	7.59E 00	4.78E 00	3.69E 00	1.96E 00	
70.00	5.42E 00	3.49E 00	2.33E 00	1.26E 00	
80.00	3.94E 00	2.58E 00	1.49E 00	8.16E-01	
90.00	2.90E 00	1.93E 00	9.65E-01	5.33E-01	
100.00	2.16E 00	1.46E 00	6.28E-01	3.50E-01	

PROTONS AS I	INCIDENT PARTICLES	SHIELD MATERIAL POLYETHYLENE
ALTITUDE OF	Y. A. SPECTRUM =	1.5000000E 03 NAUFICAL MILES
AMOIT OF V	A CETANDIN = U	0 DECEPPE

ALTITUDE OF V. A. A.	SPECTRUM = 0.0	OCCOOOLE 03 NAUFICAL DEGREES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CH2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	REM	REM
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	2.34E 02	5.84E 01	2.26E 02	4.73E 01
3.00	1.93E 02	5.49E 01	1.83E 02	4.39E 01
5.00	1.45E 02	4.87E 01	1.34E 02	3.80E 01
7.00	1.16E 02	4.35E 01	1.05E 02	3.32E 01
10.00	8.86E 01	3.70E 01	7.70E 01	2.73E 01
15.00	6.17E 01	2.89E 01	5.04E 01	2.01E 01
20.00	4.55E 01	2.30E 01	3.51E 01	1.51E 01
25.00	3.48E 01	1.86E 01	2.54E 01	1.15E 01
30.00	2.73E 01	1.52E 01	1.88E 01	8.88E 00
35.00	2.18E 01	1.25E 01	1.42E 01	6.90E 00
40.00	1.77E 01	1.04E 01	1.08E 01	5.41E 00
45.00	1.44E 01	8.68E 00	8.36E .00	4.27E 00
50.00	1.19E 01	7.30E 00	6.52E 00	3.38E 00
60.00	8.32E 00	5.23E 00	4.04E 00	2.14E 00
70.00	5.92E 00	3.82E 00	2.54E 00	1.38E 00
80.00	4.30E 00	2.82E 00	1.63E 00	8.90E-01
90.00	3.16E 00	2.10E 00	1.05E 00	5.81E-01
100.00	2.34E 00	1.58E 00	6.83E-01	3.81E-01

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TABLE A2,26

PROTONS AS INCIDENT PARTICLES SHIELD HATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL HILES ANGLE OF V. A. SPECTRUM = 0.0 DEGREES

ALTITUDE OF V.		DEGREES	HILES		
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CH2	R.T = 15.0 G/CH2	R.T = 0.0 G/CH2	R.T = 15.0 G/CM2	
SHIBLD	TUOHTIN	WITHOUT	WITH	WITH	
Depth	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
P,S (G/C#2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	2.40E 02	5.39E 01	2.37E 02	4.42E 01	249
3.00	2.07F 02	5.18E Q1	2.03E 02	4.22E 01	Ŏ
5.00	1.67E 02	4.80E 01	1.60E 02	3.85E 01	
7.00	1.4QE 02	4.46E 01	1.33E 02	3.53E 01	
10.00	1.14E 02	4.01E 01	1.05E 02	3.11E 01	
15.00	8.56E 01	3.39E 01	7.63E 01	2.54E 01	
20.00	6.75E 01	2.89E 01	5.81E 01	2.09E 01	
25.00	5.48E 01	2.49E 01	4.55E 01	1.74E 01	
30.00	4.54E 01	2.16E 01	3.63E 01	1.45E 01	
35.00	3.81E 01	1.88E 01	2.95E 01	1.22E 01	
40.00	3.23E 01	1.65E 01	2.42E 01	1.04E 01	
45.00	2.77E 01	1.45E 01	2.00E 01	8.79E 00	
50.00	2.39E 01	1.28E 01	1.67E 01	7.49E 00	
60.00	1.81E 01	1.00E 01	1.18E 01	5.49E 00	
70.00	1.402 01	7.99E 00	8.48E 00	4.07E 00	
80.00	1.10E 01	6.40E 00	6.19E 00	3.04E 00	
90.00	8.69E 00	5.17E 00	4.58E 00	2.29E 00	
100.00	6.96E 00	4.21E 00	3.41E 00	1.73E 00	

ALTITUDE OF V.	A. SPECTRUM = 1.5	IELD MATERIAL COPPE COOCOOE 03 NAUTICAL			
ANGLE OF V. A.		DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	Dose equivalent	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CH2	R,T = 0.0 G/CM2	$R_{*}T = 15.0 \text{ G/CM}2$	
SHIELD	TUOHTIW	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
2.00	PER 1.00 DAY 3.33E 02	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
3.00	2.79E 02	6.13E 01	3.29E 02	5.01E 01	250
5.00	2. 16E 02	5.88E 01	2.73E 02	4.77E 01	Č
7.00	1.79E 02	5.44E 01	2.08E 02	4.35E 01	
10.00	1.42E 02	5.04E 01	1.69E 02	3.98E 01	
15.00	1.05E 02	4.52E 01	1.31E 02	3.49E 01	
20.00	8. 16E 01	3.81E 01	9.33E 01	2.84E 01	
25.00	6.56E 01	3.24E 01	7.01E 01	2.34E 01	
30.00	5.39E 01	2.78E 01	5.44E 01	1.94E 01	
35.00	4.50E 01	2.40E 01	4.31E 01	1.62E 01	
40.00		2.09E 01	3.48E 01	1.36E 01	
45.00	3.80E 01	1.83E 01	2.84E 01	1.15E 01	
	3.24E 01	1.60E 01	2.34E 01	9.71E 00	
50.00	2.79E 01	1.41E 01	1.94E 01	8.27E 00	
60.00	2.10E 01	1.11E 01	1.36E 01	6.05E 00	
70.00	1.62E 01	8.79E 00	9.78E 00	4.47E 00	
80.00	1.26E 01	7.04E 00	7.12E 00	3.34E 00	
90.00	9.98E 00	5.67E 00	5.25E 00	2.51E 00	
100.00	7.96E 00	4.61E 00	3.90E 00	1.90E 00	

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PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

NGLE OF V. A.	$\bullet SPECTRUM = 3.0000$			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM2}$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAGRATTA	ATTENUATION	NCITAUNATIA
.S (G/CH2)	RAD	RAD	RAD	RAD
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	1.10E 02	2.48E 01	1.08E 02	2.02E 01
3.00	9.37E 01	2.36E 01	9.06E 01	1.91E 01
5.00	7.34E 01	2.15E 01	6.95E 01	1.71E 01
7.00	6.06E 01	1.97E 01	5.62E 01	1.54E 01
10.00	4.79E 01	1.73E 01	4.32E 01	1.32E 01
15.00	3.48E 01	1.42E 01	2.99E 01	1.03E 01
20.00	2.67E 01	1.18E 01	2.19E 01	8.20E 00
25.00	2.11E 01	9.90E 00	1.65E 01	6.58E 00
30.00	1.70E 01	8.37E 00	1.28E 01	5.33E 00
35.00	1.40E 01	7.13E 00	1.00E 01	4.34E 00
40.00	1.16E 01	6.12E 00	7.98E 00	3.56E 00
45.00	9.76E 00	5.27E 00	6.41E 00	2.93E 00
50.00	8.27E 00	4.56E 00	5.19E 00	2.43E 00
60.00	6.05E 00	3.46E 00	3.48E 00	1.68E 00
70.00	4.51E GO	2.65E 00	2.37E 00	1.18E CO
80.00	3.42E 00	2.06E 00	1.65E 00	8.33E-01
90.00	2.63E 00	1.61E 00	1.15E 00	5.94E-01
100.00	2.04E 00	1.27E 00	8.16E-01	4. 27E-01
	## V 7 2 V V	10215 00	0 • 10E-V i	4. 4/E-UI

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A	. SPECTRUM = 3.0000 DOSE EQUIVALENT	000E 01 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	$R_T = 0.0 \text{ G/cm}_2$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R, S (G/CM2)	REM	REM	REM	REM	
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.46E 02	2.82E 01	1.43E 02	2.30E 01	252
3.00	1.21E 02	2.69E 01	1.17E 02	2.17E 01	2
5.00	9.17E 01	2.44E 01	8.68E 01	1.94E 01	
7.00	7.44E 01	2.23E 01	6.90E 01	1.74E 01	
10.00	5.78E 01	1.96E 01	5.20E 01	1.48E 01	
15.00	4.13E 01	1.60E 01	3.54E 01	1.16E 01	
20.00	3.13E 01	1.32E 01	2.56E 01	9.16E 00	
25.00	2.45E 01	1.11E 01	1.92E 01	7.33E 00	
30.00	1.97E 01	9.33E 00	1.47E 01	5.92E 00	
35.00	1.61E 01	7.93E 00	1.15E 01	4.81E 00	
40.00	1.33E 01	6.79E 00	9.12E 00	3.94E 00	
45.00	1.11E 01	5.84E 00	7.30E 00	3.24E 00	
50.00	9.40E 00	5.04E 00	5.90E 00	•	
60.00	6.85E 00	3.81E 00	3.93E 00	2.68E 00	
70.00	5.09E 00	2.92E 00	2.67E 00	1.85E 00	
80.00	3.85E 00	2.26E 00		1.29E 00	
90.00	2.95E 00	1.77E 00	1.85E 00	9.13E-01	
100.00	2.28E 00	1.39E 00	1.29E 00	6.51E-01	
		10375 00	9.12E-01	4.67E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DECREES

ANGLE OF V. 1	A. SPECTRUM = 3.0000 ABSORBED DOSE		•••••		
	A POORDED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CH2	R,T = 15.0 G/CM2	R,T = 0.0 G/CH2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	9.43E 01	2.39E 01	9.13E 01	1.94E 01	
3.00	7.86E 01	2.24E 01	7.49E 01	1.80E 01	253
5.00	5.97E 01	1.99E 01	5.53E 01	1.56E 01	်ယ
7.00	4.80E 01	1.77E 01	4.34E 01		
10.00	3.67E 01	1.50E 01	3.19E 01	1.35E 01	
15.00	2.54E 01	1.16E 01	2.08E 01	1.11E 01	
20.00	1.86E 01	9.20E 00	1.44E 01	8. 12E 00	•
25.00	1.42E 01	7.38E 00	1.03E 01	6.06E 00	
30.00	1.10E 01	5.99E 00	7.61E 00	4.59E 00	
35.00	8.75E 00	4.91E 00	5.70E 00	3.52E 00	-
40.00	7.04E 00	4.06E 00	4.33E 00	2.72E 00	
45.00	5.73E 00	3.37E 00	3.33E 00	2.12E 00	
50.00	4.70E 00	2.82E 00		1.66E 00	
60.00	3.24E 00	2.00E 00	2.58E 00	1.31E 00	
70.00	2.29E 00	1.45E 00	1.58E 00	8.22E-01	
80.00	1.64E 00	1.06E 00	9.84E-01	5.23E-01	
90.00	1.20E 00	7.85E-01	6.23E-01	3.36E-01	
100.00	8.81E-01	5.87E-01	3.99E-01	2.17E-01	
		3.0/E-01	2.57E-01	1.42E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A.	. SPECTRUM = 3.0000	000E 01 DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R.T = 15.0 G/CH2	$R_T = 0.0 \text{ G/CM}_2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION	
R.S (G/CH2)	REM	REM	REM	рам	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	REM	
2.00	1.17E 02	2.72E 01	1.13E 02	PER 1.00 DAY	
3.00	9.53E 01	2.55E 01	9.07E 01	2.20E 01	254
5.00	7.06E 01	2.25E 01		2.04E 01	1
7.00	5.60E 01	2.00E 01	6.53E 01	1.76E 01	
10.00	4.22E 01		5.05E 01	1.52E 01	
15.00	2.89E 01	1.69E 01	3.67E 01	1.24E 01	
20.00	2.10E 01	1.30E 01	2.36E 01	9.06E 00	
25.00		1.03E 01	1.62E 01	6.74E 00	
30.00	1.59E 01	8.20E 00	1.15E 01	5.09E 00	
35.00	1.23E 01	6.65E 00	8.45E 00	3.89E 00	
	9.71E 00	5.43E 00	6.31E 00	3.00E 00	
40.00	7.79E 00	4.48E 00	4.78E 00	2.34E 00	
45.00	6.33E 00	3.72E 00	3.66E 00	1.83E 00	
50.00	5.18E 00	3.11E 00	2.83E 00	1.44E 00	
60.00	3.56E 00	2.20E 00	1.73E 00	9.01E-01	
70.00	2.50E 00	1.59% 00	1.08E 00	5.73E-01	
80.00	1.79E 00	1.16E 00	6.80E-01		
90.00	1.30E 00	8.56E-01	4.35E-01	3.67E-01	
100.00	9.58E-01	6.40E-01	2.80E-01	2.37E-01 1.54E-01	
				1.54E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A	ABSORBED DOSE	000E 01 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.21E 02	2.51E 01	1.19E 02	2.06E 01	2
3.00	1.03E 02	2.41E 01	1.01E 02	1.96E 01	255
5.00	8.21E 01	2.22E 01	7.89E 01	1.78E 01	
7.00	6.86E 01	2.06E 01	6.48E 01	1.63E 01	•
10.00	5.50E 01	1.84E 01	5.08E 01	1.43E 01	
15.00	4.08E 01	1.54E 01	3.63E 01	1.15E 01	
20.00	3.18E 01	1.31E 01	2.73E 01	9.45E 00	
25.00	2.55E 01	1.12E 01	2.12E 01	7.80E 00	
30.00	2.09E 01	9.63E 00	1.68E 01	6.49E 00	
35.00	1.74E 01	8.34E 00	1.35E 01	5.42E 00	
40.00	1.47E 01	7.26E 00	1.10E 01	4.56E 00	
45.00	1.25E 01	6.35E 00	9.01E 00	3.85E 00	
50.00	1.07E 01	5.57E 00	7.45E 00	3.27E 00	
60,00	8.02E 00	4.34E 00	5.21E 00	2.37E 00	
70.00	6.13E 00	3.41E 00	3.71E 00	1.74E 00	
80.00	4.75E 00	2.72E 00	2.68E 00	1.29E 00	-
90.00	3.73E 00	2.18E 00	1.96E 00	9.63E-01	
100.00	2.96E 00	1.76E 00	1.45E 00	7.24E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE UT V. A.	DOSE EQUIVALENT	OOOE 01 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	PATE	RATE	RATE	
	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	•
2.00	1.69E 02	2.86E 01	1.66E 02	2.34E 01	N
3.00	1.40E 02	2.74E 01	1.37E 02	2.23E 01	256
5.00	1.07E C2	2.53E 01	1.03E 02	2.02E 01	
7.00	8.79E 01	2.33E 01	8.31E 01	1.84E 01	
10.00	6.90E 01	2.08E 01	6.38E 01	1.61E 01	
15.00	5.02E 01	1.74E 01	4.47E 01	1.30E 01	
20.00	3.86E 01	1.47E 01	3.31E 01	1.06E 01	
25.00	3.07E 01	1.25E 01	2.54E 01	8.71E 00	
30.00	2.50E 01	1.08E 01	2.00E 01	7.23E 00	
35.00	2.07E 01	9.29E 00	1.60E 01	6.03E 00	
40.00	1.73E 01	8.07E 00	1.29E 01	5.06E 00	
45.00	1.47E 01	7.05E 00	1.06E 01	4.27E 00	
50.00	1.25E 01	6.18E 00	8.72E 00	3.61E 00	
60.00	9.34E 00	4.80E 00	6.05E 00	2.62E 00	
70.00	7.10E 00	3.77E 00	4.29E 00		
80.00	5.49E 00	2.99E 00	3.09E 00	1.92E 00	
90.00	4.29E 00	2.39E 00	2.26E 00	1.42E 00	
100.00	3.39E 00	1.93E 00	1.66E 00	1.06E 00 7.93E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION	•
R,S (G/CM2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	
2.00	5.48E 01	1.24E 01	5.36E 01	1.01E 01	
3.00	4.66E 01	1.18E 01	4.51E 01	9.55E 00	257
5.00	3.65E 01	1.08E 01	3.46E 01	8.56E Q0	7
7.00	3.02E 01	9.87E 00	2.80E 01	7.70E 00	
10.00	2.39E 01	8.70E 00	2.15E 01	6.61E 00	
15.00	1.74E 01	7.14E 00	1.49E 01	5.19E 00	
20.00	1.33E 01	5.93E 00	1.10E 01	4.12E 00	
25.00	1.06E 01	4.98E 00	8.29E 00	3.31E 00	
30.00	8.54E 00	4.22E 00	6.41E 00	2.68E 00	
35.00	7.02E 00	3.60E 00	5.04E 00	2. 19E 00	
40.00	5.85E 00	3.09E 00	4.02E 00	1.80E 00	
45.00	4.92E 00	2.67E 00	3.23E 00	1.48E 00	
50.00	4.17E 00	2.31E 00	2.62E 00	1.23E 00	
60.00	3.06E 00	1.75E 00	1.76E 00	8.54E-01	
70.00	2.28E 00	1.35E 00	1.20E 00	5.99E-01	
80.00	1.74E 00	1.05E 00	8.35E-01	4.24E-01	
90.00	1.34E 00	8.24E-01	5.87E-01	3.03E-01	
100.00	1.04E 00	6.52E-01	4.16E-01	2. 18E-01	

TABLE A2.35

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 6.0000 DOSE EQUIVALENT	OOOE O1 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AUN ETT A	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	7.25E 01	1.41E 01	7.11E 01	1.15E 01	N
3.00	6.00E 01	1.34E 01	5.81E 01	1.08E 01	258
5.00	4.56E 01	1,22E 01	4.32E 01	9.69E 00	
7.00	3.70E 01	1.12E 01	3.43E 01	8.70E 00	
10.00	2.88E 01	9.82E 00	2.59E 01	7.44E 00	
15.00	2.06E 01	8.02E 00	1.77E 01	5.81E 00	
20.00	1.56E 01	6.65E 00	1.28E 01	4.61E 00	
25.00	1.23E 01	5.56E 00	9.61E 00	3.69E 00	
30.00	9.86E 00	4.70E 00	7.39E 00	2.98E 00	
35.00	8.07E 00	4.00E 00	5.78E 00	2.43E 00	
40.00	6.69E 00	3.43E 00	4.58E 00	1.99E 00	
45.00	5.61E 00	2.95E 00	3.67E 00	1.64E 00	
50.00	4.74E 00	2.55E 00	2.97E 00	1.36E 00	
60.00	3.46E 00	1.93E 00	1.98E 00	9.39E-01	1 × 5.1
70.00	2.58E 00	1.48E 00	1.35E 00	6.58E-01	
80.00	1.95E 00	1.15E 00	9.37E-01	4.65E-01	
90.00	1.50E 00	9.03E-01	6.57E-01	3.32E-01	
100.00	1. 16E 00	7.14E-01	4.65E-01	2.39E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.		0000E 01 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/2M2	R.T = 15.0 G/CM2	
SHIELD	TUOHTIW	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATION	ATTENUATION	NCITAUNATIA	
2,5 (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	4.69E 01	1.20E 01	4.54E 01	9.71E 00	
3.00	3.91E 01	1.12E 01	3.73E 01	9.01E 00	259
5.00	2.97E 01	9.95E 00	2.76E 01	7.80E 00	Ψ
7.00	2.39E 01	8.87E 00	2.16E 01	6.79E 00	
10.00	1.83E 01	7.53E 00	1.59E 01		
15.00	1.27E 01	5.85E 00	1.04E 01	5.57E 00	
20.00	9.34E 00	4.64E 00	7.23E 00	4.08E 00	
25.00	7.12E 00	3.72E 00	5.20E 00	3.05E 00	
30.00	5.55E 00	3.03E 00	3.83E 00	2.32E 00	
35.00	4.41E 00	2.48E 00	2.87E 00	1.78E 00	
40.00	3.56E 00	2.06E 00		1.38E 00	
45.00	2.90E 00	1.71E 00	2.19E 00	1.07E 00	
50.00	2.38E 00	1.44E 00	1.68E 00	8.44E-01	
60.00	1.65E 00	1.02E 00	1.30E 00	6.65E-01	
70.00	1.16E 00		8.01E-01	4.19E-01	
80.00	8.38E-01	7.41E-01	5.01E-01	2.67E-01	
90.00	6.12E-01	5.44E-01	3.18E-01	1.72E-01	
100.00	4.52E-01	4.03E-01	2.04E-01	1.12E-01	
	7. JZE-U 1	3.02E-01	1.32E-01	7.28E-32	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 1.50000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R T = 0.0 G/CM2	$R_*T = 15.0 \text{ G/CM}2$	$R_T = 0.0 \text{ G/CM}_2$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM		
2.00	PER 1.00 DAY 5.81E 01	PER 1.00 DAY	PER 1.00 DAY	REM PER 1.00 DAY	
3.00	4.74E 01	1.36E 01	5.62E 01	1.10E 01	
5.00	3.51E 01	1.28E 01	4.51E 01	1.02E 01	260
7.00	3.31E 01	1.13E 01	3.25E 01		0
10.00	2.79E 01	1.00E 01	2.52E 01	8.80E 00	
15.00	2.11E 01	8.47E 00	1.83E 01	7.64E 00	
20.00	1.44E 01	6.55E 00	1.18E 01	6.25E 00	
	1.05E 01	5.17E 00	8.11E 00	4.56E 00	
25.00	7.967 00	4.14E 00	5.79E 00	3.39E 00	
30.00	6.18£ 00	3.36E 00	4.25E 00	2.57E 00	
35.00	4.89E 00	2.75E 00		1.97E 00	
40.00	3.93E 00	2.27E 00	3.18E 00	1.52E 00	
45.00	3.20E 00	1.89E 00	2.41E 00	1.18E 00	
50.00	2.62E 00	1.58E 00	1.85E 00	9.28E-01	
60.00	1.81E 00	1.12E 00	1.43E 00	7.31E-01	
70.00	1.27E 00	8.11E-01	8.77E-01	4.59E-01	
80.00	9.15E-01		5.47E-01	2.93E-01	
90.00	6.67E-01	5.94E-01	3.47E-01	1.38E-01	
100.00	4.92E-01	4.40E-01	2.22E-01	1.22E-01	
	40 J Z L = 0	3.29E-01	1.44E-01	7.94E-02	
				7 7 7 11 0 6	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE UF V. A.	ABSORBED DOSE	OOOE 01 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	$R_sT = 15.0 \text{ G/CM2}$	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	5.99E 01	1.26E 01	5.90E 01	1.03E 01	
3.00	5.14E 01	1.21E 01	5.02E 01	9.81E 00	261
5.00	4.08E 01	1.11E 01	3.92E 01		\vdash
7.00	3.41E 01	1.03E 01	3.23E 01	8.93E 00	
10.00	2.74E 01	9.23E 00	2.53E 01	8.15E 00	
15.00	2.03E 01	7.75E 00	1.81E 01	7.15E 00	
20.00	1.59E 01	6.58E 00	1.37E 01	5.80E 00	
25.00	1.28E 01	5.63E 00	1.06E 01	4.75E 00	
30.00	1.05E 01	4.85E 00		3.92E 00	
35.00	8.74E 00	4.20E 00	8.40E 00	3.27E 00	
40.00	7.37E 00	3.66E 00	6.76E 00	2.73E 00	
45.00	6.28E 00	3.21E 00	5.51E 00	2.30E 00	
50.00	5.39E 00	2.82E 00	4.53E 00	1.95E 00	
60.00	4.05E 00		3.75E 00	1.65E 00	
70.00	3. 10E 00	2.20E 00	2.63E 00	1.20E 00	
80.00		1.73E 00	1.87E 00	8.84E-01	
90.00	2.41E 00	1.38E 00	1.36E 00	6.57E-01	
100.00	1.89E 00	1.11E 00	9.96E-01	4.91E-01	
100.00	1.50E 00	8.96E-01	7.38E-01	3.70E-01	

TABLE A2.39

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 6.0000				
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	$R_{\bullet}I = 15.0 \text{ G/CM}2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	
2.00	8.39E 01	1.43E 01	8.27E 01	1.17E 01	2
3.00	6.97E 01	1.37E 01	6.81E 01	1.11E 01	262
5.00	5.34E 01	1.26E 01	5.13E 01	1.01E 01	
7.00	4.37E 01	1.17E 01	4.14E 01	9.22E 00	
10.00	3.44E 01	1.04E 01	3.18E 01	8.06E 00	
15.00	2.50E 01	8.73E 00	2.23E 01	6.51E 00	
20.00	1.93E C1	7.38E 00	1.65E 01	5.32E 00	
25.00	1.53E 01	6.30E 00	1.27E 01	4.38E 00	
30.00	1.25E C1	5.41E 00	1.00E 01	3.64E 00	
35.00	1.04E C1	4.68E 00	8.00E 00	3.04E 00	
40.00	8.70E 00	4.07E 00	6.49E 00	2.55E 00	
45.00	7.38E 00	3.56E 00	5.31E 00	2.15E 00	
50.00	6.31E CO	3.12E CO	4.39E 00	1.93E 00	
60.00	4.71E 00	2.43E 00	3.05E 00	1.32E 00	
70.00	3.59E 00	1.91E 00	2.17E 00	9.73E-01	
80.00	2.78E 00	1.52E 00	1.57E 00	7.22E-01	
90.00	2.17E 00	1.22E 00	1.14E 00	5.38E-01	
100.00	1.72E 00	9.83E-01	8.46E-01	4.05E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V.	ABSOFBED DOSE		ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/Ch2	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	RCITAUNTIA	
R.S (G/CM2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	
2.00	4.70E 01	1.07E 01	4.60E 01	8.69E 00	2
3.00	4.00E 01	1.02E 01	3.87E 01	8.22E 00	263
5.00	3.14E 01	9.27E 00	2.97E 01	7.36E 00	
7.00	2.59E 01	8.49E 00	2.41E 01	6.63E 00	
10.00	2.05E 01	7.49E 00	1.85E 01	5.69E 00	
15.00	1.50E 01	6.15E 00	1.29E 01	4.46E 00	
20.00	1.15E 01	5.11E 00	9.42E 00	3.55E 00	
25.00	9.09E 00	4.29E 00	7.13E 00	2.85E 00	
30.00	7.35E 00	3.63E 00	5.52E 00	2.31E 00	
35.00	6.05E 00	3.10E 00	4.34E 00	1.89E 00	
40.00	5.03E 00	2.66E 00	3.46E 00	1.55E 00	
45.00	4.23E 00	2.30E 00	2.78E 00	1.28E 00	
50.00	3.59E 00	1.99E 00	2.26E 00	1.06B 00	
60.00	2.63E 00	1.51E 00	1.51E 00	7.36E-01	
70. 00	1.97E 00	1.16E 00	1.04E 00	5.17E-01	
80.00	1.50E 00	9.04E-01	7.20E-01	3.66E-01	
90.00	1.15E 00	7.10E-01	5.06E-01	2.62E-01	
100.00	8.97E-01	5.62E-01	3.58E-01	1.88E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	DOSE EQUIVALENT		DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0 \cdot 0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AUN STT A	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	6.22E 01	1.21E 01	6.10E 01	9.88E 00	264
3.00	5.15E 01	1.16E 01	4.98E 01	9.32E 00	4
5.00	3.92E 01	1.05E 01	3.71E 01	8.34E 00	
7.00	3.18E 01	9.62E 00	2.95E 01	7.48E 00	
10.00	2.47E 01	8.45E 00	2.23E 01	6.40E 00	
15.00	1.77E 01	6.91E 00	1.52E 01	5.00E 00	
20.00	1.34E 01	5.72E 00	1.10E 01	3.96E 00	
25.00	1.06E 01	4.79E 00	8.27E 00	3.18E 00	
30.00	8.49E 00	4.05E 00	6.36E 00	2.57E 00	
35.00	6.94E 00	3.45E 00	4.98E 00	2.09E 00	
40.00	5.76E 00	2.95E 00	3.95E 00	1.71E 00	
45.00	4.83E 00	2.54E 00	3.16E 00	1.41E 30	
50.00	4.08E 00	2.20E 00	2.56E 00	1.17E 00	
60.00	2.98E 00	1.67E 00	1.71E 00	8.09E-01	
70.00	2.22E 00	1.28E 00	1.17E 00	5.67E-01	
80.00	1.68E 00	9.92E-01	8.08E-01	4.01E-01	
90.00	1.29E 00	7.78E-01	5.66E-01	2.86E-01	
100.00	1.00E 00	6.15E-01	4.00E-01	2.06E-01	
100.00	1.002 00	0.135-01	4.00E-01	2.00E-01	

PROTONS AS INCIDENT PARTICLES SHIFLD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 9.0000	OCCOE O1 DEGREES			
		ABSOFBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM}^2$	R.T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}^2$	$R_{\bullet}T = 15.0 \text{ G/CM2}$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	4.03E 01	1.03E 01	3.89E 01	8.35E 00	2
3.00	3.36E 01	9.66E 00	3.20E 01	7.75E 00	265
5.00	2.55E 01	8.56E 00	2.37E 01	6.71E 00	
7.00	2.06E 01	7.63E 00	1.86E 01	5.84E 00	
10.00	1.57E 01	6.48E 00	1.37E 01	4.79E 00	
15.00	1.09F 01	5.04E 00	8.96E 00	3.52E 00	
20.00	8.04E 00	3.99E 00	6.22E 00	2.63E 00	
25.00	6.12E 00	3.21E 00	4.47E 00	2.00E 00	
30.00	4.78E 00	2.61E 00	3.30E 00	1.53E 00	
35.00	3.80E 00	2.14E 00	2.47E 00	1.19E 00	
40.00	3.06E 00	1.77E 00	1.88E 00	9.26E-01	
45.00	2.50E 00	1.48E 00	1.45E 00	7.27E-01	
50.00	2.05E 00	1.24E 00	1.12E 00	5.73E-01	
60.00	1.42E 00	8.81E-01	6.90E-01	3.61E-01	
70.00	1.00E 00	6.39E-01	4.32E-01	2.31E-01	
80.00	7. 23E-01	4.69E-01	2.74E-01	1.48E-01	
90.00	5.28E-01	3.48E-01	1.76E-01	9.62E-02	
100.00	3.90E-01	2.61E-01	1.14E-01	6.27E-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A	1. SPECTRUM = 9.0000	0000E 01 DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	E.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	4.98E 01	1.17E 01	4.82E 01	9.48E 00	
3.00	4.07E 01	1.10E 01	3.87E 01	8.78E 00	266
5.00	3.02E 01	9.69E 00	2.79E 01	7.57E 00	6
7.00	2.40E 01	8.62E 00	2.16E 01	6.58E 00	
10.00	1.81E 01	7.29E 00	1.57E 01	5.37E 00	
15.00	1.24E 01	5.64E 00	1.01E 01	3.92E 00	
20.00	9.04E 00	4.45E 00	6.98E 00		
25.00	6.85E 00	3.56E 00	4.99E 00	2.92E 00	
30.00	5.32E 00	2.89E 00	3.66E 00	2.21E 00	
35.00	4.21E 00	2.37E 00	2.74E 00	1.69E 00	
40.00	3.39E 00	1.95E 00		1.31E 00	
45.00	2.75E 00	1.63E 00	2.08E 00	1.02E 00	
50.00	2.26E 00	1.36E 00	1.59E 00	8.00E-01	
60.00	1.56E 00	9.66E-01	1.23E 00	6.30E-01	
70.00	1.10E 00		7.56E-01	3.96E-01	
80.00	7.88E-01	6.99E-01	4.72E-01	2.52E-01	
90.00	5.75E-01	5.12E-01	2.99E-01	1.62E-01	
100.00		3.79E-01	1.92E-01	1.05E-01	
100.00	4.24E-01	2.84E-01	1.24E-01	6.84E-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}_2$	$R_T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
SHIELD	TUOHTIW	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	NCITAUNATTA	
R.S (G/CM2)	RAD	RAD	PAD	RAD	
2 22	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	5.14E 01	1.08E 01	5.06E 01	8.85E 00	
3.00	4.41E 01	1.04E 01	4.31E 01	8.43E 00	
5.00	3.51E 01	9.58E 00	3.37E 01	7.68E 00	
7.00	2.93E 01	8.87E 00	2.77E 01	7.02E 00	
10.00	2.35E 01	7.94E 00	2.17E 01	6.15E 00	
15.00	1.75E 01	6.67E 00	1.56E 01	4.99E CO	
20.00	1.37E 01	5.66E 00	1.17E 01	4.09E 00	
25.00	1.10E 01	4.84E 00	9.11E 00	3.38E 00	
30.00	9.02E 00	4.17E 00	7.23E 00	2.81E 00	
35.00	7.52E 00	3.62E 00	5.82E 00	2.35E CO	
40.00	6.35E 00	3.15E 00	4.74E 00	1.98E 00	
45.00	5.41E 00	2.76E 00	3.90E 00	1.68E 00	
50.00	4.64E 00	2.43E 00	3.23E 00	1.42E 00	
60.00	3.48E 00	1.89E 00	2.26E 00		
70.00	2.67E 00	1.49E 00	1.61E 00	1.03E 00	
80.00	2.07E 00	1.19E 00		7.62E-C1	
90.00	1.63E 00	9.55E-01	1.17E 00	5.66E-01	
100.00	1.30E 00		8.58E-01	4.23E-01	
10000	1.305 00	7.72E-01	6.36E-01	3.19E-01	

TABLE A2.45

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 1.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 9.0000 DOSE EQUIVALENT	OOOE 01 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.F = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	RFM	
2 22	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	7.19E 01	1.23E 01	7.09E 01	1.01E 01	268
3.00	5.98E 01	1.18E 01	5.84E 01	9.58E 00	00
5.00	4.59E 01	1.09E 01	4.41E 01	8.70E 00	
7.00	3.75E 01	1.01E 01	3.55E 01	7.93E 00	
10.00	2.95E 01	8.98E 00	2.73E 01	6.93E 00	
15.00	2.15E 01	7.51E 00	1.91E 01	5.60E 00	
20.00	1.66E 01	6.35E 00	1.42E 01	4.58E 00	
25.00	1.32E 01	5.42E 00	1.09E 01	3.77E 00	
30.00	1.08E 01	4.66E 00	8.60E 00	3. 13E 00	
35.00	8.91E 00	4.03E 00	6.89E 00	2.62E 00	
40.00	7.48E 00	3.51E 00	5.58E 00	2.20E 00	
45.00	6.35E 00	3.06E 00	4.57E 00	1.86E 00	
50.00	5.43E 00	2.69E 00	3.78E 00	1.57E 00	
60.00	4.05E 00	2.09E 00	2.63E 00		
70.00	3.09E 00			1.14E 00	
80.00	2.39E 00	1.65E 00	1.87E 00	8.38E-01	
		1.31E 00	1.35E 00	6.22E-01	
90.00	1.87E 00	1.05E 00	9.86E-01	4.64E-01	
100.00	1.49E 00	8.47E-01	7.29E-01	3.49E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM

	A. SPECTRUM = 3.0	000000E 03 NAUFICAL DEGREES	MILES		
ANGLE OF V. A	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}^2$	$R_T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AUN STT A	ATTENUATION	NCITAUNATIA	
R.S (G/CM2)	EAD	RAD	RAD	RAD	
2,0 (0,0)	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	3.79E 01	6.64E 00	3.71E 01	5.41E 00	269
3.00	3.13E 01	6.29E 00	3.03E 01	5.08E 00	•
5.00	2.35E 01	5.67E 00	2.22E 01	4.50E 00	
7.00	1.88E 01	5.13E 00	1.74E 01	4.00E 00	
10.00	1.42E 01	4.46E 00	1.28E 01	3.38E 00	
15.00	9.81E 00	3.59E 00	8.42E 00	2.60E 00	
20.00	7.22E 00	2.94E 00	5.92E 00	2.04E 00	
25.00	5.53E 00	2.44E 00	4.34E 00	1.62E 00	
30.00	4.36E 00	2.05E 00	3.27E 00	1.30E 00	
35.00	3.52E 00	1.75E 00	2.52E 00	1.06E 00	
40.00	2.89E 00	1.50E 00	1.98E 00	8.71E-01	
45.00	2.40E 00	1.30E 00	1.58E 00	7.20E-01	
50.00	2.03E 00	1.13E 00	1.27E 00	6.00E-01	
60.00	1.48E 00	8.74E-01	8.51E-01	4.24E-01	
70.00	1.12E 00	6.91E-01	5.87E-01	3.06E-01	
80.00	8.67E-01	5.57E-01	4.15E-01	2.24E-01	
90.00	6.86E-01	4.55E-01	3.00E-01	1.66E-01	
100.00	5.53E-01	3.77E-01	2.20E-01	1.25E-0 i	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM

ALTITUDE OF V ANGLE OF V. A	• SPECTRUM = 0.0		MILES DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}^2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	5.16E 01	7.64E 00	5.05E 01	6.20E 00	
3.00	4.14E 01	7.22E 00	4.00E 01	5.81E 00	270
5.00	3.00E 01	6.48E 00	2.84E 01	5.13E 00	
7.00	2.34E 01	5.85E 00	2.17E 01	4.55E 00	
10.00	1.74E 01	5.06E 00	1.57E 01		
15.00	1.18E 01	4.05E 00	1.01E 01	3.83E 00	
20.00	8.55E 00	3.30E 00	7.00E 00	2.93E 00	
25.00	6.48E 00	2.73E 00	5.07E 00	2.28E 00	
30.00	5.07E 00	2.29E 00	3.80E 00	1.81E 00	
35.00	4.06E 00	1.94E 00	2.91E 00	1.45E 00	
40.00	3.31E 00	1.66E 00	2.27E 00	1.17E 00	
45.00	2.74E 00	1.43E 00	1.80E 00	9.61E-01	
50.00	2.30E 00	1.24E 00	1.44E 00	7.93E-01	
60.00	1.67E 00	9.57E-01	9.58E-01	6.59E-01	
70.00	1.25E 00	7.54E-01	6.57E-01	4.63E-01	
80.00	9.66E-01	6.05E-01	4.62E-01	3.33E-01	
90.00	7.61E-01	4.93E-01		2.43E-01	
100.00	6.11E-01	4.93E-01	3.32E-01	1.80E-01	
	0.117	4.0/E-01	2.43E-01	1.35E-01	

PROTONS AS INC	IDENT PARTICLES SHIELD MAS	TERIAL POLYETHYLENE
ALTITUDE OF V.	A. SPECTRUM = $3.0000000E$	03 NAUFICAL MILES
ANCIE OF U A	CDECMDHH - A A	222222

ALTITUDE OF V. ANGLE OF V. A.	A. SPECTRUM = 3.0 SPECTRUM = 0.0	O00000E 03 NAUTICAL DEGREES	MILES	
anole of ve he	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	FATE	RATE	RATE	RATE
	$R_T = 0.0 \text{ G/CM}^2$	$R_{\bullet}T = 15.0 \text{ G/CM}2$	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	3.16E 01	6.38E 00	3.06E 01	5.17E 00
3.00	2.55E 01	5.94E 00	2.43E 01	4.76E 00
5.00	1.84E 01	5.18E 00	1.71E 01	4.05E 00
7.00	1.43E 01	4.56E 00	1.29E 01	3.48E 00
10.00	1.04E 01	3.80E 00	9.07E 00	2.81E 00
15.00	6.84E 00	2.89E 00	5.60E 00	2.02E 00
20.00	4.83E 00	2.26E 00	3.73E 00	1.49E 00
25.00	3.57E 00	1.81E 00	2.61E 00	1.12E 00
30.00	2.74E 00	1.47E 00	1.88E 00	8.60E-01
35.00	2.15E 00	1.21E 00	1.40E 00	6.69E-01
40.00	1.72E 00	1.01E 00	1.06E 00	5.27E-01
45.00	1.41E 00	8.55E-01	8.14E-01	4. 19 E-0 1
50.00	1.16E 00	7.29E-01	6.35E-01	3.36E-01
60.00	8.25E-01	5.44E-01	3.99E-01	2.21E-01
70.00	6.07E-01	4.17E-01	2.59E-01	1.48E-01
80.00	4.61E-01	3.27E-01	1.73E-01	1.02E-01
90.00	3.58E-01	2.61E-01	1.18E-01	7.07E-02
100.00	2.84E-01	2.11E-01	8.14E-02	4.97E-02

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUFICAL MILES

	A. SPECTRUM = 3.0		MILES		
ANGLE OF V. A.	DOSE EQUIVALENT	DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}^2$	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	
2.00	4.00E 01	7.33E 00	3.87E 01	5.92E 00	,
3.00	3.15E 01	6.80E 00	3.00E 01	5.43E 00	1
5.00	2.22E 01	5.91E 00	2.05E 01	4.61E 00	
7.00	1.69E 01	5.17E 00	1.52E 01	3.94E 00	
10.00	1.21E 01	4.30E 00	1.05E 01	3.16E 00	
15.00	7.83E 00	3.25E 00	6.39E 00	2.26E 00	
20.00	5.47E 00	2.52E 00	4.21E 00	1.66E 00	
25.00	4.01E 00	2.01E 00	2.92E 00	1.24E 00	
30.00	3.05E 00	1.62E 00	2.10E 00	9.49E-01	
35.00	2.38E 00	1.33E 00	1.55E 00	7.36E-01	
40.00	1.90E 00	1.11E 00	1.16E 00	5.77E-01	
45.00	1.55E 00	9.35E-01	8.93E-01	4.58E-01	
50.00	1.27E 00	7.95E-01	6.94E-01	3.66E-01	
60.00	8.98E-01	5.90E-01	4.34E-01	2.40E-01	
70.00	6.58E-01	4.51E-01	2.81E-01	1.61E-01	
80.00	4.97E-01	3.52E-01	1.87E-01	1.10E-01	
90.00	3.85E-01	2.80E-01	1.27E-01	7.61E-02	
100.00	3.05E-01	2.26E-01	8.74E-02	5.34E-02	

ALTITUDE OF V.	A. SPECTRUM = 3.0	IELD MATERIAL COPPER 000000E 03 NAUTICAL DEGREES	MILES		
ANGLE OF V. A.	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	BATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CH2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	PER 1.00 DAY	
2.00	4.21E 01	6.75E 00	4.14E 01	5.52E 00	2/3
3.00	3.51E 01	6.44E 00	3.43E 01	5.23E 00	
5.00	2.68E 01	5.88E 00	2.57E 01	4.71E 00	
7.00	2.16E 01	5.39E 00	2.05E 01	4.26E 00	
10.00	1.67E 01	4.76E 00	1.54E 01	3.68E 00	
15.00	1.18E 01	3.92E 00	1.05E 01	2.93E 00	
20.00	8.81E 00	3.28E 00	7.57E 00	2.37E 00	
25.00	6.86E 00	2.77E 00	5.68E 00	1.93E 00	
30.00	5.48E 00	2.37E 00	4.39E 00	1.60E 00	
35.00	4.47E 00	2.04E 00	3.46E 00	1.33E 00	
40.00	3.71E 00	1.78E 00	2.77E 00	1.12E 00	
45.00	3.11E 00	1.55E 00	2.24E 00	9.42E-01	
50.00	2.65E 00	1.37E 00	1.84E 00	8.01E-01	
60.00	1.96E 00	1.08E 00	1.27E 00	5.89E-01	
70.00	1.50E 00	8.65E-01	9.08E-01	4.41E-01	
80.00	1.17E 00	7.06E-01	6.63E-01	3.35E-01	
90.00	9.38E-01	5.83E-01	4.93E-01	2.58E-01	
100.00	7.61E-01	4.88E-01	3.73E-01	2.012-01	

PROTONS AS	INCIDENT	PARTICLES	SHIELD MATERIAL COPPER
ALTITUDE OF	V. A. SP	ECTRUM =	3.0000000E 03 NAUTICAL MILES
ANGLE OF V.	A. SPECT	RUM = 0.0	DECREE

ALTITUDE OF V	$. \ A. \ SPECTRUM = \ 3.0 $		MILES	
ANGLE OF V. A	. SPECTRUM = 0.0	DEGREES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE FQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	REM	REM
	PER 1.0C DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	6.07E 01	7.76E 00	5.99E 01	6.33E 00
3.00	4.90E 01	7.39E 00	4.79E 01	5.995 00
5.00	3.59E 01	6.73E 00	3.45E 01	5.38E 00
7.00	2.84E 01	6.16E 00	2.68E 01	4.85E 00
10.00	2.14E 01	5.42E 00	1.97E 01	4.18E 00
15.00	1.47E 01	4.44E 00	1.31E 01	3.313 00
20.00	1.08E 01	3.69E 00	9.30E 00	2.66E 00
25.00	8.33E 00	3.11E 00	6.90E 00	2.16E 00
30.00	6.60E 00	2.65E 00	5.28E 00	1.78F 00
35.00	5.34E 00	2.28E 00	4.12E 00	1.48E 00
40.00	4.40E 00	1.97E 00	3.28E 00	1.24E 00
45.00	3.67E CO	1.72E 00	2.64E 00	1.042 00
50.00	3.10E 00	1.51E 00	2.16E 00	8.83E-01
60.00	2.28E 00	1.19E 00	1.48E 00	6.46E-01
70.00	1.73E 00	9.47E-01	1.05E 00	4.822-01
80.00	1.35E 00	7.70E-01	7.59E-01	3.653-01
90.00	1.07E 00	6.35E-01	5.62E-01	2.80E-01
100.00	8.63E-01	5.30E-01	4.23E-01	2.17E-01

PROTONS AS INC	IDENT PARTICLES	SHIELD MATERIAL ALUMINUS	i
ALTITUDE OF V.	A. SPECTRUM =	3.0000000E 03 NAUFICAL M	LES
ANGLE OF V. A.	SPECTRUM = 3.0	0000000E 01 DEGREES	

ANGLE OF V. A	. SPECTRUM = 3.0000	SPECTRUM = 3.0000000E 01 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	$R_T = 15.0 \text{ G/CM}^2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AUN STT A	ATTENUATION	NCITAUNSTTA	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.74E 01	2.48E 00	1.70E 01	2.02E 00	275
3.00	1.41E 01	2.33E 00	1.36E 01	1.38E 00	0
5.00	1.02E 01	2.07E 00	9.62E 00	1.64E 00	
7.00	7.91E 00	1.85E 00	7.33E 00	1.44E GG	
10.00	5.80E 00	1.58E 00	5.22E 00	1.20E 00	
15.00	3.83E 00	1.24E 00	3.29E 00	8.97E-01	
20.00	2.72E 00	9.87E-01	2.23E 00	6.85E-01	
25.00	2.02E 00	8.00E-01	1.58E 00	5.31E-01	
30.00	1.54E 00	6.58E-01	1.16E 00	4.18E-01	
35.00	1.21E 00	5.47E-01	8.68E-01	3.32E-01	
40.00	9.68E-01	4.60E-01	6.64E-01	2.678-01	
45.00	7.86E-01	3.90E-01	5.16E-01	2.17E-01	
50.00	6.47E-01	3.33E-01	4.06E-01	- 1.77E-01	
60.00	4.54E-01	2.49E-01	2.61E-01	1.212-01	
70.00	3.30E-01	1.91E-01	1.73E-01	8.43E-02	
80.00	2.47E-01	1.49E-01	1.18E-01	6.01E-02	
90.00	1.89E-01	1.198-01	8.26E-02	4.35E-02	
100.00	1.48E-01	9.63E-02	5.89E-02	3. 19 E-0 2	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 3.0000	OOD OI DECERE	HILES		
	DOSE EQUIVALENT		DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	$R \cdot T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	2.42E 01	2.88E 00	2.37E 01	2.33E 00	2
3.00	1.89E 01	2.70E 00	1.83E 01	2.17E 00	276
5.00	1.32E 01	2.40E 00	1.25E 01	1.89E 00	
7.00	1.00E 01	2.13E 00	9.29E 00	1.66E 00	
10.00	7.21E 00	1.81E 00	6.48E 00	1.37E 00	
15.00	4.66E 00	1.41E 00	3.99E 00	1.02E 00	
20.00	3.25E 00	1.12E 00	2.66E 00	7.74E-01	
25.00	2.39E 00	9.02E-01	1.87E 00	5. 97E-01	
30.00	1.81E 00	7.39E-01	1.36E 00	4.68E-01	
35.00	1.41E 00	6.12E-01	1.01E 00	3. 71E-01	
40.00	1.12E 00	5.13E-01	7.68E-01	2.97E-01	
45.00	9.07E-01	4.34E-01	5.94E-01	2.40E-01	
50.00	7.43E-01	3.70E-01	4.65E-01	1.96E-01	
60.00	5. 17E-01	2.75E-01	2.96E-01	1.33E-01	
70.00	3.73E-01	2.09E-01	1. 95E-01		
80.00	2.77E-01	1.63E-01	1.33E-01	9.24E-02	
90.00	2.11E-01	1.29E-01	9.22E-02	6.56E-02	
100.00	1.65E-01	1.04E-01		4.73E-02	
	11035-01	1.045-01	6.55E-02	3.47E-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A	. SPECTRUM = 3.000	OOCOE 01 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTEN UATION	
R,S (G/CM2)	RAD	RAD	R A D	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.42E 01	2.37E 00	1.37E 01	1.92E 00	2
3.00	1.12E 01	2.19E 00	1.06E 01	1.75E 00	277
5.00	7.77E 00	1.87E 00	7.19E 00	1.46E 00	
7.00	5.84E 00	1.62E 00	5.26E 00	1.24E 00	
10.00	4.11E 00	1.32E 00	3.57E 00	9.75E-01	
15.00	2.56E 00	9.71E-01	2.09E 00	6.76E-01	
20.00	1.73E 00	7.34E-01	1.34E 00	4.83E-01	
25.00	1.23E 00	5.69E-01	8.98E-01	3.53E-01	
30.00	9.11E-01	4.50E-01	6.27E-01	2.64E-01	
35.00	6.93E-01	3.61E-01	4.50E-01	2.00E-01	
40.00	5.39E-01	2.94E-01	3.31E-01	1.53E-01	
45.00	4.28E-01	2.43E-01	2.48E-01	1. 19E-01	
50.00	3.45E-01	2.03E-01	1.88E-01	9.35E-02	
60.00	2.33E-01	1.45E-01	1.13E-01	5.91E~02	
70.00	1.65E-01	1.08E-01	7.05E-02	3.85E-02	
80.00	1.21E-01	8.21E-02	4.53E-02	2.56E-02	
90.00	9.10E-02	6.40E-02	3.00E-02	1.74E-02	
100.00	7.03E-02	5.07E-02	2.02E-02	1.202-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE

		OOOOOOE O3 NAUTICAL	MILES		
ANGLE OF V. A.	DOSE EQUIVALENT	OOOE O1 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	RAIL	KAIL	KAIL	RAIL	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CH2}$	$R_T = 15.0 \text{ G/CM}^2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.83E 01	2.75E 00	1.77E 01	2.22E 00	278
3.00	1.40E 01	2.53E 00	1.33E 01	2.02E 00	00
5.00	9.45E 00	2.16E 00	8.73E 00	1.68E 00	
7.00	6.98E 00	1.86E 00	6.28E 00	1.41E 30	
10.00	4.83E 00	1.51E 00	4.19E 00	1.11E 00	
15.00	2.96E 00	1.10E 00	2.41E 00	7.63E-01	
20.00	1.98E 00	8.26E-01	1.52E 00	5.42E-01	
25.00	1.40E 00	6.37E-01	1.01E 00	3.94E-01	
30.00	1.03E 00	5.01E-01	7.03E-01	2.93E-01	
35.00	7.76E-01	4.01E-01	5.02E-01	2.21E-01	
40.00	6.01E-01	3.25E-01	3.67E-01	1.69E-01	
45.00	4.74E-01	2.67E-01	2.74E-01	1.31E-01	
50.00	3.81E-01	2.22E-01	2.07E-01	1.03E-01	
60.00	2.56E-01	1.59E-01	1.24E-01	6.45E-02	
70.00	1.80E-01	1.17E-01	7.68E-02	4.18E-02	
80.00	1.31E-01	8.89E-02	4.92E-02	2.78E-02	
90.00	9.83E-02	6.90E-02	3.24E-02	1.88E-02	
100.00	7.57E-02	5.45E-02	2.18E-02	1.29E-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES

		0000000E 03 NAUTICAL	MILES		
ANGLE OF V. A.	SPECTRUM = 3.0000		ADCARDED DACE	ABCORDED DOCE	
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	PATE	RATE	
	R.T = C.O G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.96E 01	2.52E 00	1.93E 01	2.06E 00	279
3.00	1.60E 01	2.39E 00	1.56E 01	1.94E 00	79
5.00	1.18E 01	2.16E 00	1.13E 01	1.73E 00	
7.00	9.27E 00	1.96E 00	8.76E 00	1.55E 00	
10.00	6.93E 00	1.70E 00	6.40E 00	1.32E 00	
15.00	4.69E 00	1.37E 00	4.17E 00	1.02E 00	
20.00	3.39E 00	1.12E 00	2.91E 00	8.06E-01	
25.00	2.56E 00	9.25E-01	2.12E 00	6.44E-01	
30.00	1.99E 00	7.74E-01	1.59E 00	5.21E-01	
35.00	1.58E 00	6.55E-01	1.22E 00	4.25E-01	
40.00	1.28E 00	5.58E-01	9.56E-01	3.50E-01	
45.00	1.05E 00	4.79E-01	7.58E-01	2.90E-01	
50.00	8.75E-01	4.15E-01	6.09E-01	2.43E-01	
60.00	6.24E-01	3.16E-01	4.05E-01	1.73E-01	
70.00	4.60E-01	2.46E-01	2.78E-01	1.25E-01	
80.00	3.48E-01	1.95E-01	1.96E-01	9.26E-02	
90.00	2.69E-01	1.57E-01	1.42E-01	6.95E-02	
100.00	2.13E-01	1.29E-01	1.04E-01	5.292-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 3.0000	000E 01 DEGREES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	$R_T = 0.0 G/CM2$	$R_T = 15.0 \text{ G/CM2}$	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNSTEA
R.S (G/CM2)	REM	REM	REM	REM
40,000,	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	2.89E 01	2.93E 00	2.85E 01	2.39E 00
3.00	2.27E 01	2.77E 00	2.22E 01	2.25E 00
5.00	1.61E 01	2.50E 00	1.54E 01	1.99E 00
7.00	1.24E 01	2.26E 00	1.17E 01	3.78E 00
10.00	9.01E 00	1.96E 00	8.32E 00	1.51E 00
15.00	5.94E 00	1.56E 00	5.29E 00	1.16E 00
20.00	4.23E 00	1.27E 00	3.63E 00	9.14E-01
25.00	3.15E 00	1.05E 00	2.61E 00	7.27E-01
30.00	2.43E 00	8.73E-01	1.94E 00	5.86E-01
35.00	1.92E 00	7.35E-01	1.48E 00	4.76E-01
40.00	1.54E 00	6.25E-01	1.15E 00	3.912-01
45.00	1.26E 00	5.35E-01	9.04E-01	3.24E-01
50.00	1.04E 00	4.62E-01	7.22E-01	2.70E-01
60.C0	7.34E-01	3.50E-01	4.76E-01	1.91E-01
70.00	5.37E-01	2.72E-01	3.24E-01	1.38E-01
80.00	4.03E-01	2.15E-01	2.27E-01	1.01E-01
90.00	3.10E-01	1.72E-01	1.63E-01	7.59E-02
100.00	2.43E-01	1.40E-01	1.19E-01	5.76E-02

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PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 03 NAUFICAL MILES

ANGLE OF V. A.	. SPECTRUM = 6.0000	000000 01 DEGREES	HILES		
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_*T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	R A D	
2 00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	9.10E 00	1.30E 00	8.90E 00	1.05E 00	2
3.00	7.34E 00	1.22E 00	7.09E 00	9.83E-01	281
5.00	5.31E 00	1.09E 00	5.03E 00	8.59E-01	
7.00	4.13E 00	9.71E-01	3.83E 00	7.55E-01	
10.00	3.03E 00	8.28E-01	2.73E 00	6.27E-01	
15.00	2.00E 00	6.47E-01	1.72E 00	4.69E-01	
20.00	1.42E 00	5.16E-01	1.17E 00	3.58E-01	
25.00	1.05E 00	4.18E-01	8.26E-01	2.78E-01	
30.00	8.07E-01	3.44E-01	6.05E-01		
35.00	6.33E-01	2.86E-01	4.54E-01	2.18E-01	
40.00	5.06E-01	2.41E-01	3.47E-01	1.74E-01	
45.00	4.11E-01	2.04E-01	2.70E-01	1.40E-01	
50.00	3.38E-01	1.75E-01	2.12E-01	1. 13E-01	
60.00	2.37E-01	1.31E-01		9.27E-02	
70.00	1.73E-01	1.00E-01	1.36E-01	6.33E-02	
80.00	1.29E-01	7.89E-02	9.05E-02	4.43E-02	
90.00	9.95E-02	6.32E-02	6.20E-02	3.173-02	
100.00	7.83E-02	5.15E-02	4.34E-02	2.31E-02	
		3.136-02	3.11E-02	1.71E-02	

TABLE A2.59

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	DOSE EQUIVALENT	000E 01 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	NCITAUNATIA	
R,S (G/CM2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	
2.00	1.26E 01	1.50E 00	1.24E 01	1.22E 00	28
3.00	9.87E 00	1.41E 00	9.55E 00	1.14E 00	282
5.00	6.89E 00	1.25E 00	6.52E 00	9.90E-01	
7.00	5.24E 00	1.12E 00	4.85E 00	8.67E-01	
10.00	3.77E 00	9.49E-01	3.39E 00	7.17E-01	
15.00	2.44E 00	7.37E-01	2.09E 00	5.33E-01	
20.00	1.70E 00	5.85E-01	1.39E 00	4.04E-01	
25.00	1.25E 00	4.72E-01	9.77E-01	3.12E-01	
30.00	9.49E-01	3.86E-01	7.09E-01	2.45E-01	
35.00	7.39E-01	3.20E-01	5.28E-01	1.94E-01	
40.00	5.87E-01	2.68E-01	4.01E-01	1.55E-01	
45.00	4.74E-01	2.27E-01	3.10E-01	1.26E-01	
50.00	3.88E-01	1.93E-01	2.43E-01	1.02E-01	
60.00	2.70E-01	1.44E-01	1.55E-01	6.97E-02	
70.00	1.95E-01	1.10E-01	1.02E-01	4.85E-02	
80.00	1.45E-01	8.61E-02	6.95E-02	3.46E-02	
90.00	1.11E-01	6.87E-02	4.84E-02	2.51E-02	
100.00	8.70E-02	5.58E-02	3.45E-02	1.85E-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUFICAL MILES

ANGLE OF V. A.	SPECTRUM = 6.0000	0000E 01 DEGREES	1 DC 0 D D D D D C C	ADCORDED DACE	
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AUN BTT A	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	7.43E 00	1.24E 00	7.18E 00	1.00E 00	283
3.00	5.84E 00	1.14E 00	5.56E 00	9.14E-01	ω
5.00	4.06E 00	9.81E-01	3.76E 00	7.66E-01	
7.00	3.05E 00	8.48E-01	2.75E 00	6.47E-01	
10.00	2.15E 00	6.92E-01	1.87E 00	5.10E-01	
15.00	1.34E 00	5.08E-01	1.10E 00	3.53E-01	
20.00	9.06E-01	3.84E-01	6.99E-01	2.52E-01	
25.00	6.45E-01	2.97E-01	4.70E-01	1.85E-01	
30.00	4.76E-01	2.35E-01	3.28E-01	1.38E-01	
35.00	3.62E-01	1.89E-01	2.35E-01	1.04E-01	
40.00	2.82E-01	1.54E-01	1.73E-01	8.02E-02	
45.00	2.24E-01	1.27E-01	1.29E-01	6.24E-02	
50.00	1.80E-01	1.07E-01	9.84E-02	4.91E-02	
60.00	1. 22E-01	7.69E-02	5.92E-02	3.12E-02	
70.00	8.69E-02	5.75E-02	3.71E-02	2.05E-02	
80.00	6.41E-02	4.42E-02	2.40E-02	1.37E-02	
90.00	4.88E-02	3.48E-02	1.60E-02	9.42E-03	
100.00	3.81E-02	2.79E-02	1.09E-02	6.57E-03	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 6.0000	000E 01 DEGREES		
	DOSE EQUIVALENT		DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}_2$
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	NCITAUNSTTA
R.S (G/CM2)	REM	REM	REM	REM
2 44	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	9.55E 00	1.44E 00	9.23E 00	1.16E 00
3.00	7.31E 00	1.32E 00	6.96E 00	1.05E 00
5.00	4.94E 00	1.13E 00	4.56E 00	8.80E-01
7.00	3.65E 00	9.722-01	3.29E 00	7.40E-01
10.00	2.53E 00	7.89E-01	2.19E 00	5.80E-01
15.00	1.55E 00	5.75E-01	1.26E 00	3.99 = -01
20.00	1.04E 00	4.32E-01	7.96E-01	2.83E-01
25.00	7.31E-01	3.33E-01	5.30E-01	2.06E-01
30.00	5.36E-01	2.62E-01	3.68E-01	1.53E-01
35.00	4.05E-01	2.09E-01	2.63E-01	1.152-01
40.00	3.14E-01	1.70E-01	1.92E-01	
45.00	2.48E-01	1.40E-01	1.43E-01	8.85E-02
50.00	1.99E-01	1.17 = -01		6.86E-02
60.00	1. 34E-01	8.38E-02	1.08E-01	5.38E-02
70.00	9.46E-02		6.48E-02	3.40E-02
80.00		6.23E-02	4.04E-02	2.22E-02
	6.94E-02	4.77E-02	2.61E-02	1.49E-02
90.00	5.26E-02	3.74E-02	1.73E-02	1.02E-02
100.00	4.09E-02	2.99E-02	1.17E-02	7.07E-03

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PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

	SPECTRUM = 6.0000	OOOE O1 DEGREES	HILLS		
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CH2	$R_T = 0.0 \text{ G/CH2}$	$R_*T = 15.0 \text{ G/CH2}$	
SHIELD	WITHOUT	WITHOUT	HTIW	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATPENUATION	
R.S (G/CH2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.03 DAY	
2.00	1.02E 01	1.32E 00	1.01E 01	1.08E 30	2
3.00	8.33E 00	1.25E 00	8.14E 00	1.02E 00	285
5.00	6.14E 00	1.13E 00	5.90E 00	9.04E-01	
7.00	4.84E 00	1.022 00	4.58E 00	8. 09E-01	
10.00	3.62E 00	8.91E-01	3.34E 00	6.882-01	
15.00	2.45E 00	7.162-01	2.182 00	5.342-01	
20.00	1.77E 00	5.85E-01	1.52E 00	4.21E-01	
25.00	1.34E 00	4.84E-01	1.11E 00	3.37E-01	
30.00	1.04E 00	4.05E-01	8.34E-01	2.728-01	
35.00	8.29E-01	3.42E-01	6.40E-01	2.222-01	
40.00	6.70E-01	2.92E-01	5.00E-01	1.83E-01	
45.00	5.51E-01	2.51E-01	3.97E-01	1.52E-01	
50.00	4.58E-01	2.17E-01	3.18E-01	1.272-01	
60.00	3.26E-01	1.66E-01	2.12E-01	9.03E-02	
70.00	2.41E-01	1.29E-01	1.45E-01	6.57E-02	
80.00	1.82E-01	1.03E-01	1.03E-01	4.87E-02	
90.00	1. 4 1E-01	8.312-02	7.42E-02	3.67E-02	
100.00	1.12E-01	6.832-02	5.47E-02	2.80E-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	• SPECTEUM = 6.0000	OOOE 01 DEGREES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE SQUIAYFEML
	PATE	RATE	RATE	RATE
	E.T = 0.0 G/CM2	R.T = 15.0 G/CH2	R.T = 0.0 G/CH2	B.T = 15.0 G/CH2
SHIELD	WITHOUT	TUOHTIE	HIIN	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	MCITAUMSTTA
E.S (G/CM2)	REM	REM	RZM	REM
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	1.51E 01	1.53E 00	1.49E 01	1. 25% 00
3.00	1.192 01	1.45E 00	1.16E 01	1.178 00
5.00	8.39E 00	1.312 00	8.06E 00	1.042 00
7.00	6.45E 00	1.18E 00	6.10E 00	9.302-01
10.00	4.71E 00	1.02E 00	4.352 00	7.898-01
15.00	3.11E 00	8.18E-01	2.77E 00	6.092-01
20.00	2.21E 00	6.65E-01	1.90E 00	4.78E-01
25.00	1.65E 00	5.48E-01	1.37E 00	
30.00	1.27E 00	4.562-01	1.022 00	3.80E-01
35.00	1.00E 00	3.842-01	7.73E-01	3.062-01
40.00	8.05E-01	3.27E-01	6.00E-01	2.498-01
45.00	6.57E-01	2.80E-01	4.73E-01	2.04E-01
50.00	5. 43E-01	2.41E-01	3.78E-01	1.69E-01
60.00	3.84E-01	1.83E-01	2.49E-01	1.412-01
70.00	2.80E-01	1.42E-01		9.982-02
80.00	2.11E-01	1. 13E-01	1.692-01	7.23E-02
90.00	1.62E-01	9.00E-02	1.192-01	5.33E-02
100.00	1.28E-01		8.53E-02	4.00 E-02
	1.202-07	7.44E-02	6.25E-02	3.05E-02

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	ABSORBED DOSE	0000E 01 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
				KB3OKBED D33E
	RATE	RATE	RATE	RATE
	F.T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM2}$	R.T = 0.0 G/382	R.I = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	7.77E 00	1.11E 00	7.60E 00	9.05E-01
3.00	6.27E CO	1.05E 00	6.06E 00	8.44E-01
5.00	4.54E 00	9.32E-01	4.30E 00	7.38E-01
7.00	3.53E 00	8.34E-01	3.27E 00	5.49E-01
10.00	2.60E 00	7.12E-01	2.34E 00	5. 39E-01
15.00	1.72E 00	5.58E-01	1.47E 00	
20.00	1.22E 00	4.46E-01	9.99E-01	4.04E-01
25.00	9.06E-01	3.62E-01	7.10E-01	3.09E-01
30.00	6.95E-01	2.98E-01	5.20E-01	2.40E-01
35.00	5.46E-01	2.49E-01		1.89E-01
40.00	4. 37E-01	2.10E-01	3.91E-01	1.512-01
45.00	3.56E-01		3.00E-01	1.22E-01
50.00	2.94E-01	1.78E-01	2.33E-01	9.91E-02
60.00	2.94E-01	1.53E-01	1.84E-01	8.13E-02
70.00	1.51E-01	1. 15E-01	1.19E-01	5.59E-02
80.00		8.94E-02	7.94E-02	3.94E-02
90.00	1.14E-01	7.08E-02	5.47E-02	2.84E-02
	8.86E-02	5.72E-02	3.86E-02	2.09E-02
100.00	7.03E-02	4.70E-02	2.79E-02	1.55E-02

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 9.0000				
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	BATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	#ITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNSTTA	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.30 DAY	
2.00	1.08E 01	1.29E 00	1.06E 01	1.052 00	
3.00	8.42E 00	1.21E 00	8.15E 00	9. 75E-01	288
5.00	5.89E 00	1.08E 00	5.57E 00	9.50E-01	90
7.00	4.48E GO	9.59E-01	4.15E 00	7.44E-01	
10.00	3.22E 00	8.15E-01	2.90E 00	6. 16E-01	
15.00	2.09E 00	6.35E-01	1.79E 00	4.59E-01	
20.00	1.46E 00	5.04E-01	1.19E 00		
25.00	1.07E 00	4.08E-01	8.39E-01	3.49E-01	
30.00	8.15E-01	3.35E-01	6.10E-01	2.70E-01	
35.00	6.36E-01	2.78E-01	4.55E-01	2.12E-01	
40.00	5.06E-01	2.33E-01		1.68E-01	
45.00	4.10E-01	1.98E-01	3.46E-01	1.35E-01	
50.00	3.37E-01	1.69E-01	2.68E-01	1.10E-01	
60.00	2.35E-01		2.11E-01	8.97E-02	
70.00	1.71E-01	1.27E-01	1.35E-01	6.14E-02	
80.00		9.77E-02	8.94E-02	4.31E-02	
	1.282-01	7.71E-02	6.12E-02	3.09E-02	
90.00	9.87E-02	6.20E-02	4.308-02	2.26E-02	
100.00	7.78E-02	5.08E-02	3.09E-02	1.688-02	

PROTONS AS	INCIDENT	PARTICLES	SHIELD MA	TERIAL POLYE	THYLENE
ALTITUDE OF	V. A. S	PECTRUM =	3.0000000E	03 NAUTICAL	MILES
		- A 1	10 000000	D D C D D D C	

		OOOOOOE O3 NAUFICAL		
ANGLE OF V. A.		OCOE O1 DEGREES		
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	RATE	PATE	RATE	RATE
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	E.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	6.34E 00	1.06E 00	6.13E 00	8.61E-01
3.00	4.99E 00	9.82E-01	4.75E 00	7.85E-01
5.00	3.47E 00	8.42E-01	3.21E 00	6.58E-01
7.00	2.61E 00	7.29E-01	2.36E 00	5.56E-01
10.00	1.84E 00	5.96E-01	1.60E 00	4.393-01
15.00	1.15E 00	4.38E-01	9.40E-01	3.05E-01
20.00	7.78E-01	3.32E-01	6.01E-01	2.182-01
25.00	5.56E-01	2.58E-01	4.05E-01	1.603-01
30.00	4.12E-01	2.05E-01	2.83E-01	1.20E-01
35.00	3.14E-01	1.65E-01	2.04E-01	9.13E-02
40.00	2.45E-01	1.36E-01	1.50E-01	7.05E-02
45.00	1.95E-01	1.13E-01	1.13E-01	5.51E-02
50.00	1.58E-01	9.47E-02	8.62E-02	4.36E-02
60.00	1.08E-01	6.91E-02	5.23E-02	2.80E-02
70.00	7.77E-02	5.22E-02	3.31E-02	1.85E-02
80.00	5.80E-02	4.06E-02	2.17E-02	1.26E-02
90.00	4.46E-02	3.23E-02	1.46E-02	8.72E-03
100.00	3.52E-02	2.62E-02	1.00E-02	6.15E-03

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUFICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 04 DEGREES

ANGLE OF V. A.	. SPECTRUM = 9.0000	OOOD OI DECERE	HILES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIBLD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM	REM	
2.00	8. 15E 00		PER 1.00 DAY	PER 1.00 DAY	
3.00	6.25E 00	1.23E 00	7.88E 30	9.95E-01	
5.00	4.22E 00	1.13E 00	5.94E 00	9.05E-31	
7.00		9.69E-01	3.90E 00	7.55E-01	
10.00	3. 12E 00	8.36E-01	2.81E 00	6.36E-01	
	2.16E 00	6.79E-01	1.88E 00	4.99E-01	
15.00	1.33E 00	4.96E-01	1.08E 00	3.44E-01	
20.00	8.89F-01	3.74E-01	6.84E-01	2.45E-01	
25.00	6.29E+01	2.89E-01	4.57E-01	1.79E-01	
30.00	4.63E-01	2.28E-01	3.17E-01	1.33E-01	
35.00	3.51E-01	1.83E-01	2.27E-01	1.01E-01	
40.00	2.73E-01	1.49E-01	1.67E-01	7. 76E-02	
45.00	2. 16E-01	1.24E-01	1.25E-01		
50. 00	1.74E-01	1.04E-01	9.48E-02	6.05E-02	
60.00	1.18E-01	7.51E-02	5.72E-02	4.76E-02	
70.00	8.44E-02	5.65E-02		3.04E-02	
80.00	6.26E-02	4.37E-02	3.60E-02	2.01E-02	
90.00	4.80F-02		2.35E-02	1.36E-02	
1.00.00	3.77E-02	3.47E-02	1.57E-02	9.38E-03	
	J. //E-02	2.80E-02	1.08E-02	6.60E-03	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. 1	A. SPECTRUM = 9.000				
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM2}$	$R_{\bullet}T = 0.0 \text{ G/CH2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	MCITAUMSTTA	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	
2.00	8.72E 00	1.13E 00	8.59E 00	9.24E-01	,
3.00	7.12E 00	1.07E 00	6.95E 00	8.71E-01	
5.00	5.25E 00	9.70E-01	5.04E 00	7.76E-01	
7.00	4.14E 00	8.80E-01	3.91E 00	6.95E-01	
10.00	3.10E 00	7.66E-01	2.86E 00	5.92E-01	
15.00	2.10E 00	6.16E-01	1.87E 00	4.60E-01	
20.00	1.52E 00	5.04E-01	1.31E 00	3.63E-01	
25.00	1.15E 00	4.18E-01	9.53E-01	2.91E-01	
30.00	8.95E-01	3.50E-01	7.16E-01	2.36E-01	
35.00	7.13E-01	2.97E-01	5.51E-01	1.93E-01	
40.00	5.78E-01	2.54E-01	4.31E-01	1.59E-01	
45.00	4.75E-01	2.18E-01	3.42E-01	1.32E-01	
50.00	3.96E-01	1.90E-01	2.75E-01	1.11E-01	
60.00	2.83E-01	1.45E-01	1.84E-01	7.93E-02	
70.00	2. 10E-01	1.14E-01	1.27E-01	5.80E-02	
80.00	1.60E-01	9.14E-02	9.00E-02	4.33E-02	
90.00	1.25E-01	7.44E-02	6.54E-02	3.28E-02	
100.00	9.91E-02	6.16E-02	4.85E-02	2.53E-02	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 3.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

	SPECTRUM = 9.0000 DGSE EQUIVALENT	COOE 01 DEGREES	DOSE EQUIVALENT	DOSE EQUIVALENT
	DOSE EQUIVABLA	DODE NEGLETAL	DODE EQUIVADUAL	Door Bear means
	RATE	RATE	RATE	RATE
	$R_T = 0.0 \text{ G/CM}2$	$R_T = 15.0 \text{ G/CM}2$	$R_T = 0.0 \text{ G/CM2}$	R,I = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
P.S (G/CM2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY
2.00	1.29E 01	1.31E 00	1.27E 01	1.07E 00
3.00	1.01E 01	1.25E 00	9.91E 00	1.01E 00
5.00	7.17E 00	1.12E 00	6.89E 00	8.95E-01
7.00	5.51E 00	1.01E 00	5.21E 00	7.99E-01
10.00	4.02E 00	8.79E-01	3.72E 00	6.78E-01
15.00	2.66E 00	7.04E-01	2.37E 00	5.24E-01
20.00	1.89E 00	5.73E-01	1.63E 00	4.12E-01
25.00	1.41E 00	4.73E-01	1.17E 00	3.28E-01
30.00	1.09E 00	3.95E-01	8.72E-01	2.65E-01
35.00	8.61E-01	3.33E-01	6.65E-01	2.16E-01
40.00	6.93E-01	2.84E-01	5.16E-01	1.77E-01
45.00	5.67E-01	2.43E-01	4.08E-01	1.47E-01
50.00	4.69E-01	2.11E-01	3.26E-01	1.23E-01
60.00	3.33E-01	1.61E-01	2.15E-01	8.75E-02
70.00	2.44E-01	1.26E-01	1.47E-01	6.37E-02
80.00	1.84E-01	1.00E-01	1.04E-01	4.73E-02
90.00	1.43E-01	8.12E-02	7.50E-02	3.57E-02
100.00	1.13E-01	6.69E-02	5.53E-02	2.74E-02

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 4.5000C00E 03 NAUTICAL MILES

ALTITUDE OF V. A. ANGLE OF V. A.		OOOCOOE O3 NAUTICAL DEGREES	MILES		
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	BATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUN STTA	ATTENUATION	ATTENUATION	
R.S (G/CM2)	ŔAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	6.32E 00	1.25E-01	6.18E 00	1.01E-01	293
3.00	4.17E 00	1.10E-01	4.02E 00	8.81E-02	ũ
5.00	2.20E 00	8.61E-02	2.08E 00	6.76E-02	
7.00	1.33E 00	6.79E-02	1.23E 00	5.24E-02	
10.00	7.14E-01	4.83E-02	6.40E-01	3.62E-02	
15.00	3.06E-01	2.84E-02	2.61E-01	2.04E-02	
20.00	1.50E-01	1.72E-02	1.22E-01	1.18E-02	
25.00	8.02E-02	1.07E-02	6.24E-02	7.07E-03	
30.00	4.53E-02	6.88E-03	3.37E-02	4.33E-03	
35.00	2.67E-02	4.48E-03	1.90E-02	2.70E-03	
40.00	1.63E-02	2.96E-03	1.11E-02	1.71E-03	
45.00	1.02E-02	1.99E-03	6.66E-03	1.10E-03	
50.00	6.55E-03	1.35E-03	4.08E-03	7:15E-04	_
60.00	2.83E-03	6.42E-04	1.62E-03	3.11E-04	
70.00	1.30E-03	3.15E-04	6.80E-04	1.40E-04	
80.00	6.18E-04	1.60E-04	2.96E-04	6.48E-05	
90.00	3.04E-04	8.33E-05	1.33E-04	3.08E-05	
100.00	1.55E-04	4.43E-05	6.19E-05	1.492-05	

PROTONS AS INC	IDENT PARTICLES	SHIELD MATERIAL ALUMINUM
ALTITUDE OF V.	A. SPECTRUM =	4.5000000E 03 NAUTICAL MILES
ANGLE OF V. A.	SPECTRUM = 0.0	DEGREES

DOSE EQUIVALENT RATE RATE RATE R,T = 0.0 G/CM2 R,T = 15.0 G/CM2 R,T = 0.0 G/CM2 R,T = 15.0 G SHIELD WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUATION	
SHIELD WITHOUT WITH WITH	
	/CM2
DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUATI	
	O N
R,S (G/CN2) REN REN REN	
PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY PER 1.00	DAY
2.00 1.00E 01 1.57E-01 9.82E 00 1.26E-01	
3.00 6.34E 00 1.38E-01 6.13E 00 1.10E-01	
5.00 3.19E 00 1.07E-01 3.02E 00 8.40E-02	
7.00 1.88E 00 8.42E-02 1.73E 00 6.48E-02	
10.00 9.78E-01 5.95E-02 8.76E-01 4.46E-02	
15.00 4.08E-01 3.47E-02 3.48E-01 2.49E-02	
20.00 1.97E-01 2.09E-02 1.60E-01 1.44E-02	
25.00 1.03E-01 1.30E-02 8.04E-02 8.54E-03	
30.00 5.78E-02 8.29E-03 4.29E-02 5.20E-03	
35.00 3.39E-02 5.38E-03 2.41E-02 3.23E-03	
40.00 2.05E-02 3.54E-03 1.39E-02 2.04E-03	
45.00 1.28E-02 2.37E-03 8.31E-03 1.31E-03	
50.00 8.16E-03 1.61E-03 5.08E-03 8.49E-04	
60.00 3.50E-03 7.61E-04 2.00E-03 3.67E-04	
70.00 1.59E-03 3.72E-04 8.33E-04 1.64E-04	
80.00 7.55E-04 1.88E-04 3.61E-04 7.60E-05	
90.00 3.69E-04 9.77E-05 1.62E-04 3.60E-05	
100.00 1.87E-04 5.18E-05 7.49E-05 1.74E-05	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUFICAL MILES

		MILES		
		ADCODDED DOCE	ADCARDED DACE	
	RDSORDED DOSE	RESURBED DJSE	ABSJRBED DJSE	
RATE	RATE	RATE	RATE	
R T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	
WITHOUT	WITHOUT	WITH	WITH	
ATTENUATION	NCITAUN STT A	ATTENUATION	ATTENUATION	
RAD	RAD	RAD	RAD	
PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
	1.14E-01	4.17E 00	9.15E-02	295
	9.62E-02	2.55E 00	7.63E-02	5
1.30E 00	6.95E-02	1.20E 00	5.38E-02	
7.33E-01	5.09E-02	6.57E-01	3.85E-02	
3.58E-01	3.28E-02	3.09E-01	2.40E-02	
1.35E-01	1.66E-02	1.09E-01		
5.88E-02	8.87E-03	4.49E-02		
2.83E-02	4.92E-03	2.04E-02	3.03E-03	
1.45E-02	2.81E-03	9.86E-03		
7.80E-03	1.65E-03	5.02E-03		
4.35E-03	9.91E-04			
2.51E-03	6.04E-04			
1.48E-03	3.73E-04			
5.44E-04				
2.13E-04				
8.80E-05				
3.77E-05				
1.66E-05	5.59E-06	4.94E-06	1.38E-06	
	SPECTRUM = 0.0 ABSORBED DOSE RATE R.T = 0.0 G/CM2 WITHOUT ATTENUATION RAD PER 1.00 DAY 4.32E 00 2.69E 00 1.30E 00 7.33E-01 3.58E-01 1.35E-01 5.88E-02 2.83E-02 2.83E-02 1.45E-02 7.80E-03 4.35E-03 4.35E-03 2.51E-03 1.48E-03 5.44E-04 2.13E-04 8.80E-05 3.77E-05	SPECTRUM = 0.0 DEGREES ABSORBED DOSE RATE RATE RATE RATE RATE WITHOUT WITHOUT RAD PER 1.00 DAY 4.32E 00 1.14E-01 2.69E 00 9.62E-02 1.30E 00 6.95E-02 7.33E-01 3.28E-02 1.35E-01 1.66E-02 5.88E-02 8.7E-03 2.83E-02 4.92E-03 1.45E-02 2.81E-03 7.80E-03 1.65E-03 4.35E-03 9.91E-04 2.51E-03 6.04E-04 1.48E-03 3.73E-04 5.44E-04 1.50E-04 2.13E-04 6.29E-05 8.80E-05 2.72E-05 3.77E-05 1.22E-05	RATE RATE RATE RAD PER 1.00 DAY PER 1.00	SPECTRUM = 0.0 ABSORBED DOSE ABSORBED DOSE ABSORBED DOSE ABSORBED DOSE RATE RATE RATE RATE RATE RATE RATE WITHOUT WITH WITH ATTENUATION ATTENUATION ATTENUATION ATTENUATION RAD RAD RAD RAD PER 1.00 DAY PER 1.00 DAY

PROTONS AS INC	IDENT PARTICLES	SHIELD MATERIAL POLYETHYLENE
		4.5000000E 03 NAUFICAL MILES
ANGIR OF U.A		

	A. SPECTRUM = 4.50	00000E 03 NAUTICAL	MILES	
ANGLE OF V. A.	SPECTRUM = 0.0	DEGREES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNSTTA	ATTENUATION	NCITAUNSTTA
R.S (G/CM2)	REM	REM	REM	REM
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	6.20E 00	1.43E-01	5.98E 00	1.14E-01
3.00	3.73E 00	1.20E-01	3.54E 00	9.49E-02
5.00	1.73E 00	8.62E-02	1.60E 00	6.66E-02
7.00	9.54E-01	6.28E-02	8.54E-01	4.74E-02
10.00	4.56E-01	4.02E-02	3.93E-01	2.93E-02
15.00	1.67E-01	2.02E-02	1.35E-01	1.39E-02
20.00	7.22E-02	1.07E-02	5.50E-02	6.96E-03
25.00	3.43E-02	5.91E-03	2.47E-02	3.63E-03
30.00	1.74E-02	3.36E-03	1.18E-02	1.96E-03
35.00	9.34E-03	1.97E-03	6.00E-03	1.08E-03
40.00	5.19E-03	1.18E-03	3.15E-03	6.11E-04
45.00	2.97E-03	7.14E-04	1.71E-03	3.50E-04
50.00	1.75E-03	4.40E-04	9.50E-04	2.04E-04
60.00	6.39E-04	1.76E-04	3.09E-04	7.25E-05
70.00	2.49E-04	7.36E-05	1.08E-04	2.68E-05
80.00	1.02F-04	3.18E-05	3.92E-05	1.02E-05
90.00	4.38E-05	1.42E-05	1.47E-05	3.99E-06
100.00	1.93E-05	6.49E-06	5.71E-06	1.60E-06

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER
ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES
ANGLE OF V. A. SPECTRUM = 0.0

		OOOOOOE 03 NAUTICAL	MILES		
ANGLE OF V. A.		DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM} 2$	R,T = 15.0 G/CM2	R,T = 0.0 G/3M2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ACITAUN STT A	ATTENUATION	MCITAUNATIA	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	7.80E 00	1.30E-01	7.68E 00	1.05E-01	297
3.00	5.27E 00	1.16E-01	5.14E 00	9.35E-02	7
5.00	2.90E 00	9.38E-02	2.78E 00	7.44E-02	
7.00	1.80E 00	7.63E-02	1.70E 00	5.97E-02	
10.00	1.01E 00	5.66E-02	9.27E-01	4.33E-02	
15.00	4.56E-01	3.53E-02	4.05E-01	2.61E-02	
20.00	2.35E-01	2.27E-02	2.01E-01	1.62E-02	
25.00	1.31E-01	1.49E-02	1.08E-01	1.03E-02	
30.00	7.70E-02	9.95E-03	6.14E-02	6.63E-03	
35.00	4.71E-02	6.77E-03	3.63E-02	4.36E-03	
40.00	2.98E-02	4.67E-03	2.22E-02	2.90E-03	
45.00	1.93E-02	3.26E-03	1.39E-02	1.96E-03	
50.00	1.28E-02	2.30E-03	8.86E-03	1.34E-03	
60.00	5.92E-03	1.18E-03	3.82E-03	6.385-04	
70.00	2.88E-03	6.19E-04	1.73E-03	3. 137-04	
80.00	1.46E-03	3.34E-04	8.202-04	1.58E-04	
90.00	7.61E-04	1.84E-04	3.99E-04	8.122-05	
100.00	4.08E-04	1.04E-04	2.00E-04	4.27E-05	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 0.0 DEGREES DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT RATE RATE PATE RATE R,T = 0.0 G/CM2 R,T = 15.0 G/CM2R,T = 0.0 G/CM2 R,P = 15.0 G/CM2SHIFID

SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	
2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 35.00 40.00 45.00 50.00 60.00 70.00 80.00	REM PER 1.00 DAY 1.33E 01 8.62E 00 4.49E 00 2.71E 00 1.46E 00 6.42E-01 3.24E-01 1.78E-01 1.78E-01 1.03E-01 6.27E-02 3.93E-02 2.54E-02 1.67E-02 7.64E-03 3.69E-03 1.86E-03 9.65E-04	REM PER 1.00 DAY 1.63E-01 1.45E-01 1.17E-01 9.47E-02 6.99E-02 4.33E-02 2.77E-02 1.81E-02 1.20E-02 8.17E-03 5.62E-03 3.91E-03 2.75E-03 1.40E-03 7.35E-04 3.95E-04 2.17E-04	REM PER 1.00 DAY 1.32E 01 8.43E 00 4.32E 00 2.56E 00 1.35E 00 5.70E-01 2.77E-01 1.47E-01 8.23E-02 4.82E-02 2.92E-02 1.82E-02 1.15E-02 4.93E-03 2.22E-03 1.04E-03 5.06E-04	REM PER 1.00 DAY 1.32E-01 1.17E-01 9.25E-02 7.40E-02 5.34E-02 3.20E-02 1.97E-02 1.24E-02 8.01E-03 5.25E-03 3.48E-03 2.34E-03 1.59E-03 7.57E-04 3.71E-04 1.86E-04
	5.15E-04	1.22E-04	2.52E-04	9.54E-05 5.01E-05

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A.	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	P.T = 15.0 G/CH2	R,T = 0.0 G/382	a,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCIT AU METTA
R,S (G/CM2)	RAD PER 1.00 DAY	RAD	RAD	EAU
2.00	2.69E 00	PER 1.00 DAY 4.52E-02	PER 1.00 DAY	PER 1.00 DAY
3.00	1.66E 00	4.00E-02	2.63E 00	3.65E-02
5.00	8.14E-01	3.17E-02	1.60E 00	3.20E-02
7.00	4.76E-01	2.52E-02	7.68E-01	2.492-02
10.00	2.50E-01	1.83E-02	4.39E-01	1.95E-02
15.00	1.08E-01		2.24E-01	1.37E-02
20.00	5.40E=02	1.11E-02	9.20E-02	7.95E-03
25.00	2.96E-02	6.92E-03	4.40E-02	4.76E-03
30.00		4.46E-03	2.30E-02	2.94E-03
35.00	1.72E-02	2.93E-03	1.28E-02	1.85E-03
	1.05E-02	1.97E-03	7.45E-03	1.19E-03
40.00	6.58E-03	1.34E-03	4.492-03	7.76E-04
45.00	4.25E-03	9.27E-04	2.77E-03	5.12E-04
50.00	2.81E-03	6.47E-04	1.75E-03	3.42E-04
60.00	1.29E-03	3.24E-04	7.38E-04	1.57E-04
70.00	6.23E+04	1.68E-04	3.26E-04	7.45E-05
80.00	3.13E-04	8.95E-05	1.502-04	3.62E-05
90.00	1.63E-04	4.88E-05	7.14E-05	1.80E-05
160.00	8.68E-05	2.72E-05	3.48E-05	9.13E-06

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A	. SPECTRUM = 3.0000	000E 01 DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CH2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.30 DAY	
2.00	4.41E 00	5.64E-02	4.32E 00	4.542-02	w
3.00	2.58E 00	4.97E-02	2.50E 00	3.97E-02	300
5.00	1.19E 00	3.92E-02	1.13E 00	3.07E-02	
7.00	6.74E-01	3.11E-02	6.23E-01		
10.00	3.43E-01	2.24E-02	3.08E-01	2.40E-02	
15.00	1.43E-01	1.34E-02	1.22E-01	1.68E-02	
20.00	7.02E-02	8.36E-03	5.71E-02	9.64E-03	
25.00	3.79E-02	5.36E-03		5.74E-03	
30.00	2. 18E-02	3.51E-03	2.95E-02	3.52E-03	
35.00	1.32E-02	2.35E-03	1.62E-02	2.21E-03	
40.00	8.22E-03	1.60E-03	9.36E-03	1.41E-03	
45.00	5.28E-03	1.10E-03	5.59E-03	9.20E-04	
50.00	3.47E-03		3.44E-03	6.05E-04	
60.00	1.58E-03	7.65E-04	2.16E-03	4.03E-04	
70.00	7.60E-04	3.81E-04	9.03E-04	1.84E-04	
80.00	3.79E-04	1.97E-04	3.97E-04	8.72E-05	
90.00	1.96E-04	1.05E-04	1.82E-04	4.23E-05	
100.00		5.69E-05	8.60E-05	2.09E-05	
100.00	1.04E-04	3.16E-05	4.17E-05	1.06E-05	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DECREES

ANGLE OF V. A	. SPECTRUM = 3.000	0000E 01 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	BATE	
	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CH2	
SHIELD	TUOHTIW	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.73E 00	4.14E-02	1.67E 00	3.32E-02	361
3.00	1.02E 00	3.52E-02	9.63E-01	2.79E-02	£:
5.00	4.65E-01	2.58E-02	4.28E-01	2.00E-02	
7.00	2.57E-01	1.92E-02	2.31E-01	1.45E-02	
10.00	1.26E-01	1.27E-02	1. 08E-01	9.288-03	
15.00	4.85E-02	6.70E-03	3.93E-02	4.63E-03	
20.00	2.20E-02	3.72E-03	1.68E-02	2.43E-03	
25.00	1. 10E-02	2.15E-03	7.95E-03	1.33E-03	
30.00	5.89E-03	1.28E-03	4.02E-03		
35.00	3.30E-03	7.80E-04	2.13E-03	7.47E-04	
40.00	1.92E-03	4.84E-04		4.30E-04	
45.00	1.15E-03	3.06E-04	1.17E-03	2.53E-04	
50.00	7.03E-04	1.97E-04	6.62E-04	1.51E-04	
60.00	2.78E-04		3.83E-04	9.15E-05	
70.00	1.17E-04	8.41E-05	1.35E-04	3.47E-05	
80.00	5. 12E-05	3.76E-05	5.05E-05	1.37E-05	
90.00	2.34E-05	1.74E-05	1.96E-05	5.58E-06	
100.00		8.24E-06	7.91E-06	2.32E-06	
100.00	1.10E-05	3.99E-06	3.26E-06	9.84E-07	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES

100.00

1.27E-05

ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT RATE RATE RATE RATE $R_T = 0.0 \text{ G/CM}^2$ R.T = 15.0 G/CH2R.T = 0.0 G/CM2R.T = 15.0 G/CM2SHIELD WITHOUT WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUATION R.S (G/CM2) REM REM REM REM PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 2.00 5.15E-02 2.54E 00 2.45E 00 4.12E-02 3.00 1.43E 00 1.35E 00 3.45E-02 4.36E-02 5.00 6.23E-01 3.18E-02 5.73E-01 2.46E-02 7.00 3.35E-01 2.35E-02 1.78E-02 3.00E-01 10.00 1.60E-01 1.55E-02 1.38E-01 1.13E-02 15.00 8.08E-03 6.01E-02 4.86E-02 5.57E-03 20.00 2.68E-02 4.46E-03 2.05E-02 2.90E-03 25.00 2.56E-03 1.33E-02 9.57E-03 1.58E-03 30.00 7.05E-03 8.84E-04 1.52E-03 4.80E-03 35.00 3.92E-03 9.22E-04 2.52E-03 5.07E-04 40.00 2.27E-03 1.38E-03 5.70E-04 2.97E-04 45.00 3.60E-04 1.35E-03 1.77E-04 7.78E-04 50.00 2.31E-04 8.26E-04 4.48E-04 1.07E-04 60.00 3.25E-04 9.82E-05 1.58E-04 4.04E-05 70.00 1.36E-04 4.37E-05 5.86E-05 1.59E-05 80.00 5.93E-05 2.01E-05 2.27E-05 6.46E-36 90.00 2.70E-05 9.53E-06 9.12E-06 2.68E-06

4.61E-06

3.75E-06

302

1.13E-06

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A.	. SPECTRUM = 3.0000	000000 01 DEGREES	HILES		
	ABSCRBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM}_2$	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTE NUATION	ATTENUATION	ATPENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	3.44E 00	4.68E-02	3.39E 00	3.80E-02	w
3.00	2.16E 00	4.21E-02	2.11E 00	3.39E-02	303
5.00	1.10E 00	3.43E-02	1.05E 00	2.73E-02	
7.00	6.56E-01	2.82E-02	6.19E-01	2.73E-02	
10.00	3.55E-01	2.12E-02	3.27E-01	1.63E-02	
15.00	1.60E-01	1.36E-02	1.42E-01	1.01E-02	
20.00	8.31E-02	8.95E-03	7.11E-02	6.40E-03	
25.00	4.72E-02	6.04E-03	3.90E-02	4.17E-03	
30.00	2.85E-02	4.15E-03	2.27E-02	2.77E-03	
35.00	1.79E-02	2.90E-03	1.38E-02	1.87E-03	
40.00	1.16E-02	2.05E-03	8.64E-03		
45.00	7.73E-03	1.47E-03	5.55E-03	1.28E-03 8.83E-04	
50.00	5.26E-03	1.06E-03	3.65E-03		
60.00	2.56E-03	5.69E-04		6. 17E-04	
70.00	1.31E-03	3.13E-04	1.65E-03 7.90E-04	3.08E-04	
80.00	6.95E-04	1.77E-04		1.59E-04	
90.00	3.80E-04	1.02E-04	3.91E-04	8.38E-05	
100.00	2.13E-04	6.01E-05	1.99E-04 1.05E-04	4.50E-05	
		0.012-03	1.035-04	2.47E-05	

PROTONS AS INC	IDENT PARTICLES SHE	IELD MATERIAL COP	PER
ALTITUDE OF V.	A. SPECTRUM = 4.50 SPECTRUM = 3.0000	OOOOOOE O3 NAUTIC	AL MILES
	DOSE EQUIVALENT	DOSE EQUIVALEN	T DOS

and DD of v. R.	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R.T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM2}$	$R_T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	REM	REM
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	6.14E 00	5.84E-02	6.06E 00	4.73E-02
3.00	3.65E 00	5.24E-02	3.57E 00	4.21E-02
5.00	1.73E 00	4.25E-02	1.66E 00	3.37E-02
7.00	9.95E-01	3.48E-02	9.40E-01	2.72E-02
10.00	5.18E-01	2.61E-02	4.78E-01	1.99E-02
15.00	2.24E-01	1.66E-02	1.99E-01	1.23E-02
20.00	1.14E-01	1.09E-02	9.76E-02	7.75E-03
25.00	6.38E-02	7.28E-03	5.26E-02	5.02E-03
30.00	3.80E-02	4.99E-03	3.03E-02	3.32E-03
35.00	2.36E-02	3.47E-03	1.81E-02	2. 23E-03
40.00	1.52E-02	2.44E-03	1.13E-02	1.52E-03
45.00	1.00E-02	1.75E-03	7.20E-03	1.05E-03
50.00	6.79E-03	1.26E-03	4.71E-03	7.31E-04
60.00	3.27E-03	6.73E-04	2.11E-03	
70.00	1.66E-03	3.69E-04	1.00E-03	3.64E-04
80.00	8.78E-04	2.08E-04		1.86E-04
90.00	4.77E-04	1.20E-04	4.93E-04	9.81E-05
100.00	2.67E-04		2.50E-04	5. 26E-05
	2.0/E-04	7.02E-05	1.31E-04	2.87E-05

PROTONS AS I	INCI	DENT PARTIC	LES	SHIELD MAT	TERIAL ALUMI	NUM
ALTITUDE OF	V.	A. SPECTRUM	=	4.5000000E	03 NAUTICAL	MILES
ANGLE OF V.	λ	SDECTRUM =	6 (000000E 01	DECDEES	

	SPECTRUM = 6.0000	000E 01 DEGREES	HILLS		
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$	$R_T = 0.0 G/SM2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTE NU ATION	ATTENUATION	NCITAUNATTA	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.35E 00	2.45E-02	1.32E 00	1.98E-02	305
3.00	8.51E-01	2.17E-02	8.22E-01	1.74E-02	5
5.00	4.28E-01	1.72E-02	4.04E-01	1.35E-02	
7.00	2.53E-01	1.37E-02	2.34E-01	1.06E-02	
10.00	1.35E-01	9.92E-03	1.21E-01	7.46E-03	
15.00	5.84E-02	6.01E-03	4.98E-02	4.32E-03	
20.00	2.93E-02	3.76E-03	2.38E-02	2.59E-03	
25.00	1.61E-02	2.42E-03	1.25E-02	1.59E-03	
30.00	9.34E-03	1.59E-03	6.96E-03	1.00E-03	
35.00	5.68E-03	1.07E-03	4.05E-03	6.45E-04	
40.00	3.57E-03	7.29E-04	2.44E-03	4.21E-04	
45.00	2.31E-03	5.03E-04	1.51E-03	2.78E-04	
50.00	1.52E-03	3.51E-04	9.50E-04	1.85E-04	
60.00	7.00E-04	1.75E-04	4.00E-04	8.51E-05	
70.00	3.38E-04	9.10E-05	1.77E-04	4.03E-05	
80.00	1.69E-04	4.85E-05	8.14E-05	1.96E-05	
90.00	8.81E-05	2.64E-05	3.86E-05	9.73E-06	
100.00	4.70E-05	1.47E-05	1.88E-05	4.93E-06	

PROTONS AS INC	IDENT PARTICLES	SHIELD MAS	ERIAL ALUMINUM
			03 NAUTICAL MILES
	SPECTRUM = 6.		

ANGLE OF V. A.	. SPECTRUM = 6.0000			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R, T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CH2)	REM	REM	REM	REM
2 22	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	2.20E 00	3.06E-02	2.16E 00	2.46E-02
3.00	1.32E 00	2.70E-02	1.27E 00	2.16E-02
5.00	6.26E-01	2.13E-02	5.91E-01	1.67E-02
7.00	3.58E-01	1.69E-02	3.31E-01	1.30E-02
10.00	1.84E-01	1.22E-02	1.65E-01	9.11E-03
15.00	7.74E-02	7.30E-03	6.60E-02	5.24E-03
20.00	3.81E-02	4.54E-03	3.10E-02	3. 12E-03
25.00	2.06E-02	2.91E-03	1.60E-02	1.91E-03
30.00	1.18E-02	1.91E-03	8.81E-03	1. 20E-03
35.00	7.15E-03	1.27E-03	5.08E-03	7.67E-04
40.00	4.46E-03	8.66E-04	3.04E-03	4.99E-04
45.00	2.87E-03	5.96E-04	1.87E-03	3.28E-04
50.00	1.88E-03	4.15E-04	1.17E-03	2. 19E-04
60.00	8.59E-04	2.06E-04	4.90E-04	
70.00	4. 12E-04	1.07E-04	2.15E-04	9.99E-05
80.00	2.05E-04	5.66E-05	9.85E-05	4.72E-05
90.00	1.06E-04	3.07E-05		2.29E-05
100.00	5.65E-05		4.66E-05	1.13E-05
100.00	J. UJE-UJ	1.71E-05	2.26E-05	5.72E-06

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUFICAL MILES

ANGLE OF V. A.	SPECTRUM = 6.0000	0000E 01 DEGREES	HILES		
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_*F = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
3.00	8.88E-01	2.25E-02	8.56E-01	1.80E-02	30/
5.00	5.31E-01	1.91E-02	5.03E-01	1.52E-02	`
	2.48E-01	1.40E-02	2.28E-01	1.09E-02	
7.00	1.38E-01	1.04E-02	1.24E-01	7.90E-03	
10.00	6.80E-02	6.89E-03	5.87E-02	5.04E-03	
15.00	2.63E-02	3.64E-03	2.13E-02	2.51E-03	
20.00	1.19E-02	2.02E-03	9.14E-03	1.32E-03	
25.00	5.98E-03	1.17E-03	4.32E-03	7.20E-04	
30.00	3.20E-03	6.95E-04	2.18E-03	4.05E-04	
35.00	1.79E-03	4.23E-04	1. 15E-03	2.33E-04	
40.00	1.04E-03	2.62E-04	6.36E-04	1.37E-04	
45.00	6.23E-04	1.66E-04	3.59E-04	8. 18E-05	
50.00	3.81E-04	1.06E-04	2.08E-04	4.95E-05	
60.00	1.51E-04	4.55E-05	7.33E-05		
70. 00	6.32E-05	2.03E-05	2.73E-05	1.88E-05	
80.00	2.77E-05	9.39E-06	1.06E-05	7.41E-06	
90.00	1.27E-05	4.44E-06	4.27E-06	3.01E-06	
100.00	5.94E-06	2.15E-06		1.25E-06	
		2.132-90	1.76E-06	5.30E-07	

PROTONS AS INCIDENT PARTICI	LES SHIELD MATERIAL POLYETHYLENE
ALTITUDE OF V. A. SPECTRUM	= 4.5000000E 03 NAUTICAL MILES
ANGLE OF V. A. SPECTRUM =	6.000000F 01 DEGREES

ANGLE OF V. A	A. SPECTRUM = 6.0000	000E 01 DEGREES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM2}$
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	A TTEN UA TIO N	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	REM
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	1.29E 00	2.79E-02	1.25E 00	2.24E-02
3.00	7.42E-01	2.37E-02	7.04E-01	1.87E-02
5.00	3.31E-01	1.73E-02	3.05E-01	1.33E-02
7.00	1.80E-01	1.28E-02	1.61E-01	9.66E-03
10.00	8.63E-02	8.40E-03	7.43E-02	6.12E-03
15.00	3.26E-02	4.39E-03	2.64E-02	3.02E-03
20.00	1.46E-02	2.42E-03	1.11E-02	1.58E-03
25.00	7.22E-03	1.39E-03	5.20E-03	8.56E-04
30.00	3.83E-03	8.25E-04	2.60E-03	4.80E-04
35.00	2. 13E-03	5.00E-04	1.37E-03	2.75E-04
40.00	1.23E-03	3.09E-04	7.50E-04	1.61E-04
45.00	7.35E-04	1.95E-04	4.22E-04	9.59E-05
50.00	4.48E-04	1.25E-04	2.43E-04	5.79E-05
60.00	1.76E-04	5.31E-05	8.54E-05	2.19E-05
70.00	7.34E-05	2.36E-05	3.17E-05	8.60E-06
80.00	3.21E-05	1.09E-05	1.23E-05	3.49E-06
90.00	1.46E-05	5.14E-06	4.93E-06	1.45E-06
100.00	6.84E-06	2.48E-06	2.03E-06	6.12E-07

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 6.0000	0000E 01 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	
2.00	1.71E 00	2.54E-02	1.69E 00	2.06E-02	309
3.00	1.10E 00	2.29E-02	1.07E 00	1.84E-02	9
5.00	5.72E-01	1.86E-02	5.49E-01	1.48E-02	
7.00	3.47E-01	1.53E-02	3.28E-01	1.20E-02	
10.00	1.90E-01	1.15E-02	1.75E-01	8.83E-03	
15.00	8.62E-02	7.38E-03	7.66E-02	5.47E-03	
20.00	4.50E-02	4.86E-03	3.85E-02	3.48E-03	
25.00	2.56E-02	3.28E-03	2.12E-02	2.26E-03	
30.00	1.55E-02	2.25E-03	1.23E-02	1.50E-03	
35.00	9.71E-03	1.57E-03	7.47E-03	1.01E-03	
40.00	6.31E-03	1.11E-03	4.69E-03	6.92E-04	
45.00	4.20E-03	7.97E-04	3.01E-03	4.79E-04	
50.00	2.86E-03	5.76E-04	1.98E-03	3.35E-04	
60.00	1.39E-03	3.08E-04	8.96E-04	1.67E-04	
70.00	7.10E-04	1.70E-04	4.28E-04	8.59E-05	
80.00	3.77E-04	9.60E-05	2.12E-04	4.53E-05	
90.00	2.06E-04	5.54E-05	1.08E-04	2.44E-05	
100.00	1.16E-04	3.25E-05	5.66E-05	1.33E-05	

TABLE A2.87

	CIDENT PARTICLES SH	IELD MATERIAL COPPER	1		
	A. SPECTRUM = 4.5	OOOOOOE O3 NAUTICAL	MILES		
ANGLE OF V. A.	SPECTRUM = 6.0000	000E 01 DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM} 2$	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNATIA	
R.S (G/CH2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	3.02E 00	3.17E-02	2.98E 00	2.56E-02	w
3.00	1.84E 00	2.85E-02	1.80E 00	2.29E-02	310
5.00	8.98E-01	2.31E-02	8.63E-01	1.83E-02	
7.00	5.24E-01	1.89E-02	4.95E-01	1.48E-02	
10.00	2.77E-01	1.42E-02	2.56E-01	1.08E-02	
15.0 0	1.21E-01	9.01E-03	1.08E-01	6.66E-03	
20.00	6.18E-02	5.90E-03	5.29E-02	4.21E-03	
25.00	3.46E-02	3.95E-03	2.86E-02	2.73E-03	
30.00	2.06E-02	2.71E-03	1.64E-02	1.80E-03	
35.00	1.28E-02	1.88E-03	9.85E-03	1.21E-03	
40.00	8.26E-03	1.33E-03	6.13E-03	8.24E-04	
45.00	5.45E-03	9.48E-04	3.91E-03		
50.00	3.69E-03	6.84E-04	2.56E-03	5.69E-04	
60.00	1.77E-03	3.65E-04	1.15E-03	3.96E-04	
70.00	9.02E-04	2.00E-04	5.43E-04	1.97E-04	
80.00	4.76E-04	1.13E-04	2 698-04	1.01E-04	

1.13E-04

6.48E-05

3.79E-05

2.68E-04

1.36E-04

7.08E-05

5.31E-05

2.85E-05

1.55E-05

80.00

90.00

100.00

4.76E-04 2.59E-04

1.45E-04

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES

SPECTRUM = 9.0000000E 01 DEGREES					
ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE		
RATE	RATE	RATE	RATE		
$R_T = 0.0 \text{ G/CM} 2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$		
WITHOUT	WITHOUT	WITH	WITH		
ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION		
RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY		
				μ	
				311	
3.69E-01	1.47E-02				
2.18E-01	1.17E-02				
1. 15E-01	8.45E-03	1.03E-01			
4.99E-02	5.11E-03	4.26E-02	3.68E-03		
2.50E-02	3.20E-03	2.04E-02	2.20E-03		
1.37E-02	2.06E-03	1.07E-02	1.36E-03		
7.96E-03	1.36E-03	5.93E-03	8.53E-04		
4.84E-03	9.09E-04	3.45E-03	5.49E-04		
3.04E-03	6.20E-04	2.07E-03	3.58E-04		
1.97E-03	4.27E-04	1.28E-03	2.36E-04		
1.30E-03	2.98E-04	8.08E-04	1.58E-04		
5.95E-04	1.49E-04	3.40E-04	7.248-05		
2.87E-04	7.74E-05	1.50E-04	3.43E-05		
1.44E-04	4.12E-05	6.92E-05	1.672-05		
7.49E-05	2.24E-05	3.28E-05	8.278-06		
3.99E-05	1.25E-05	1.60E-05	4.192-06		
	SPECTRUM = 9.0000 ABSORBED DOSE RATE R.T = 0.0 G/CM2 WITHOUT ATTENUATION RAD PER 1.00 DAY 1.17E 00 7.34E-01 3.69E-01 2.18E-01 1.15E-01 4.99E-02 2.50E-02 1.37E-02 7.96E-03 4.84E-03 3.04E-03 3.04E-03 1.97E-03 1.30E-03 5.95E-04 2.87E-04 1.44E-04 7.49E-05	SPECTRUM = 9.0000000E 01 DEGREES ABSORBED DOSE ABSORBED DOSE RATE RATE R.T = 0.0 G/CM2 R,T = 15.0 G/CM2 WITHOUT ATTENUATION RAD PER 1.00 DAY PER 1.00 DAY 1.17E 00 2.09E-02 7.34E-01 1.85E-02 3.69E-01 1.47E-02 1.15E-01 8.45E-03 4.99E-02 5.11E-03 2.50E-02 3.20E-03 1.37E-02 2.06E-03 7.96E-03 1.36E-03 4.84E-03 9.09E-04 3.04E-03 6.20E-04 1.97E-03 4.27E-04 1.30E-03 2.98E-04 5.95E-04 7.74E-05 1.44E-04 7.74E-05 7.49E-05 2.24E-05	SPECTRUM = 9.0000000E 01 DEGREES ABSORBED DOSE ABSORBED DOSE RATE RATE RATE RATE R.T = 0.0 G/CM2 R.T = 0.0 G/CM2 WITHOUT WITH WITH ATTENUATION ATTENUATION ATTENUATION BAD RAD RAD PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 1.17E 00 2.09E-02 1.14E 00 7.34E-01 1.85E-02 7.09E-01 3.69E-01 1.47E-02 3.48E-01 2.18E-01 1.17E-02 2.01E-01 1.5E-01 8.45E-03 1.03E-01 4.99E-02 5.11E-03 4.26E-02 2.50E-02 3.20E-03 2.04E-02 1.37E-02 2.06E-03 1.07E-02 7.96E-03 1.36E-03 5.93E-03 4.84E-03 9.09E-04 3.45E-03 3.04E-03 6.20E-04 2.07E-03 1.97E-03 4.27E-04 1.28E-03 1.30E-03 2.98E-04	SPECTRUM = 9.00000000E 01 DEGREES ABSORBED DOSE ABSORBED	

TABLE A2.89

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000CE 01 DEGREES

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
				DOSE EQSIVALENT	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM} 2$	$R_T = 15.0 \text{ G/CM}^2$	R.T = 0.0 G/CM2	R,r = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.90E 00	2.6 1E-02	1.86E 00	2, 10E-02	(
3.00	1.14E 00	2.30E-02	1.10E 00	1.84E-02	+
5.00	5.39E-01	1.81E-02	5.09E-01	1.42E-02	
7.00	3.08E-01	1.44E-02	2.84E-01	1.11E-02	
10.00	1.58E-01	1.04E-02	1.42E-01	7.77E-03	
15.00	6.62E-02	6.22E-03	5.64E-02	4.46E-03	
20.00	3.25E-02	3.86E-03	2.648-02	2.65E-03	
25.00	1.76E-02	2.48E-03	1.37E-02	1.63E-03	
30.00	1.01E-02	1.62E-03	7.51E-03	1.02E-03	
35.00	6.09E-03	1.08E-03	4.33E-03	6.52E-04	
40.00	3.80E-03	7.37E-04	2.58E-03		
45.00	2.44E-03	5.07E-04	1.59E-03	4.24E-04	
50.00	1.60E-03	3.53E-04	9.97E-04	2.79E-04	
60.00	7.30E-04	1.76E-04	4.16E-04	1.86E-04	
70.00	3.50E-04	9.07E-05	1.83E-04	8.50E-05	
80.00	1.75E-04	4.81E-05	8.38E-05	4.01E-05	
90.00	9.04E-05	2.61E-05		1.94E-05	
100.00	4.80E-05	1.45E-05	3.96E-05	9.62E-06	
		1.43E-03	1.92E-05	4.87E-06	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_* P = 0.0 G/CM2$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	7.66E-01	1.92E-02	7.38E-01	1.54E-02	w
3.00	4.57E-01	1.63E-02	4.33E-01	1.29E-02	313
5.00	2.13E-01	1.19E-02	1.96E-01	_	•
7.00	1. 18E-01	8.89E-03	1.06E-01	9.25E-03	
10.00	5.82E-02	5.87E-03	5.02E-02	6.73E-03	
15.00	2.24E-02	3.10E-03	1.82E-02	4.29E-03	
20.00	1.02E-02	1.72E-03	7.79E-03	2.14E-03	
25.00	5.09E-03	9.92E-04		1.12E-03	
30.00	2.72E-03	5.91E-04	3.68E-03	6.13E-04	
35.00	1.52E-03	3.60E-04	1.86E-03	3.45E-04	
40.00	8.86E-04	2.27E-04	9.82E-04	1.98E-04	
45.00	5.30E-04	1.41E-04	5.41E-04	1.16E-04	
50.00	3.24E-04		3.05E-04	6.96E-05	
60.00	1. 28 E-04	9.05E-05	1.76E-04	4.21E-05	
70.00	5.37E-05	3.87E-05	6.24E-05	1.59E-05	
80.00	2.35E-05	1.73E-05	2.32E-05	6.30E-06	
90.00	1.08E-05	7.98E-06	9.02E-06	2.56E-06	
100.00	5.05E-06	3.78E-06	3.63E-06	1.06E-06	
	J. 03E-06	1.83E-06	1.50E-06	4.51E-07	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/3M2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.12E 00	2.38E-02	1.08E 00	1.91E-02	۰
3.00	6.39E-01	2.02E-02	6.07E-01	1.60E-02	31 4
5.00	2.84E-01	1.47E-02	2.62E-01	1.14E-02	•
7.00	1.54E-01	1.09E-02	1.38E-01	8.23E-03	
10. 00	7.38E-02	7.15E-03	6.36E-02	5.22E-03	
15.00	2.78E-02	3.74E-03	2.25E-02	2.57E-03	
20.00	1.24E-02	2.06E-03	9.48E-03	1.34E-03	
25.00	6.15E-03	1.18E-03	4.43E-03	7.28E-04	
30.00	3.26E-03	7.01E-04	2.22E-03	4.08E-04	
35.00	1.81E-03	4.25E-04	1.16E-03		
40.00	1.05E-03	2.63E-04	6.38E-04	2.34E-04	
45.00	6.25E-04	1.66E-04	3.59E-04	1.37E-04	
50.00	3.81E-04	1.06E-04	2.07E-04	8.16E-05	
60.00	1.50E-04	4.52E-05		4.92E-05	
70.00	6.24E-05	2.01E-05	7.26E-05	1.86E-05	
80.00	2.73E-05	9.25E-06	2.69E-05	7.31E-06	
90.00	1.24E-05		1.04E-05	2.97E-06	
100.00	5.81E-06	4.37E-06	4.19E-06	1.23E-06	
	J. 0 1E-00	2.11E-06	1.72E-06	5.20E-07	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM} 2$	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNTITA	
R,S (G/CM2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.30 DAY	
2.00	1.48E 00	2.17E-02	1.46E 00	1.76E-02	μ
3.00	9.50E-01	1.95E-02	9.28E-01	1.57E-02	315
5.00	4.93E-01	1.59E-02	4.73E-01	1.26E-02	
7.00	2.98E-01	1.31E-02	2.82E-01	1.02E-02	
10.00	1.63E-01	9.82E-03	1.50E-01	7.52E-03	
15.00	7.38E-02	6.29E-03	6.55E-02	4.66E-03	
20.00	3.85E-02	4.14E-03	3.29E-02	2.96E-03	
25.00	2.19E-02	2.79E-03	1.81E-02	1.93E-03	
30.00	1.32E-02	1.92E-03	1.05E-02	1.28E-03	
35.00	8.27E-03	1.34E-03	6.37E-03	8.61E-04	
40.00	5.37E-03	9.45E-04	3.99E-03	5.89E-04	
45.00	3.57E-03	6.77E-04	2.56E-03	4.08E-04	
50. 00	2.43E-03	4.90E-04	1.69E-03	2.85E-04	
6 0. 00	1.18E-03	2.62E-04	7.62E-04	1.42E-04	
70.00	6.04E-04	1.44E-04	3.64E-04	7.31E-05	
80.00	3.21E-04	8.16E-05	1.80E-04	3.86E-05	
90.00	1.75E-04	4.71E-05	9.19E-05	2.07E-05	
100.00	9.83E-05	2.76E-05	4.82E-05	1.13E-05	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 4.5000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A	1. SPECTRUM = 9.0000	0000E 01 DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}2$	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM2}$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATIENUATION	
R,S (G/CM2)	REM	REN	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	2.61E 00	2.71E-02	2.58E 00	2.19E-02	316
3.00	1.59E 00	2.43E-02	1.55E 00	1.95E-02	6
5.00	7.74E-01	1.97E-02	7.44E-01	1.56E-02	
7.00	4.51E-01	1.61E-02	4.26E-01	1.26E-02	
10.00	2.38E-01	1.21E-02	2.19E-01	9.22E-03	
15.00	1.04E-01	7.67E-03	9.20E-02	5.67E-03	
20.00	5.28E-02	5.02E-03	4.52E-02	3.58E-03	
25.00	2.95E-02	3.37E-03	2.44E-02	2.32E-03	
30.00	1.76E-02	2.31E-03	1.40E-02	1.53E-03	
35.00	1.09E-02	1.60E-03	8.39E-03	1.03E-03	
40.00	7.03E-03	1.13E-03	5.22E-03	7.01E-04	
45.00	4.64E-03	8.06E-04	3.33E-03	4.84E-04	
50.00	3.14E-03	5.82E-04	2.18E-03	3.37E-04	
60.00	1.51E-03	3.10E-04	9.74E-04	1.68E-04	
70.00	7.67E-04	1.70E-04	4.62E-04	8.58E-05	
80.00	4.05E-04	9.58E-05	2.28E-04	4.52E-05	
90.00	2.20E-04	5.51E-05	1.15E-04	2.42E-05	
100.00	1.23E-04	3.23E-05	6.02E-05	1.32E-05	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES

		0000000E 03 NAUTICAL	MILES		
ANGLE OF V. A.	ABSORBED DOSE	DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 G/2M2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATION	ATTENUATION	NCITAUNTTA	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.23E-01	6.18E-06	1.21E-01	4.95E-06	31
3.00	4.85E-02	4.34E-06	4.69E-02	3.45E-06	7
5.00	1.08E-02	2.18E-06	1.02E-02	1.70E-06	
7.00	3.14E-03	1.12E-06	2.89E-03	8.56E-07	
10.00	6.46E-04	4.26E-07	5.77E-04	3.17E-07	
15.00	6.95E-05	9.30E-08	5.91E-05	6.61E-08	
20.00	9.95E-06	2.21E-08	8.06E-06	1.50E-08	
25.00	1.74E-06	5.63E-09	1.34E-06	3.66E-09	
30.00	3.45E-07	1.53E-09	2.55E-07	9.53E-10	
35.00	7.62E-08	4.38E-10	5.39E-08	2.61E-10	
40.00	1.833-08	1.31E-10	1.24E-08	7.46E-11	
45.00	4.72E-09	4.03E-11	3.05E-09	2.20E-11	
50.00	1.29E-09	1.27E-11	7.98E-10	6.65E-12	
60.00	1.12E-10	1.34E-12	6.33E-11	6.42E-13	
70.00	1.09E-11	1.53E-13	5.68E-12	6.72E-14	
80.00	1. 16E-12	1.92E-14	5.51E-13	7.70E-15	
90.00	1. 33E-13	2.61E-15	5.81E-14	9.56E-16	
100.00	1.68E-14	3.76E-16			
100.00	1.005-14	3. / OL- 10	6.70E-15	1.25E-16	

PROTONS AS INC	IDENT PARTICLES	SHIELD MATERIAL ALUMI	NUM
ALTITUDE OF V.	A. SPECTRUM =	6.0000000E 03 NAUTICAL	MILES
ANGLE OF V. A.	SPECTRUM = 0.0	DEGREES	
	DOSE EQUIVALENT	T DOSE EQUIVALENT	DOS

ANGLE OF V. A.	SPECTRUM = 0.0	DEGREES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R.T = 0.0 G/CM2	R,T = 15.0 G/CH2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	REM	REM
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	2.37E-01	8.97E-06	2.33E-01	7.18E-06
3.00	8.91E-02	6.28E-06	8.62E-02	4.98E-06
5.00	1.89E-02	3.14E-06	1.78E-02	2.44E-06
7.00	5.29E-03	1.60E-06	4.88E-03	1.22E-06
10.00	1.05E-03	6.05E-07	9.41E-04	4.50E-07
15.00	1.10E-04	1.31E-07	9.33E-05	9.29E-08
20.00	1.53E-05	3.08E-08	1.24E-05	2.09E-08
25.00	2.63E-06	7.79E-09	2.04E-06	5.07E-09
30.00	5.17E-07	2.10E-09	3.82E-07	1.31E-09
35.00	1.13E-07	5.99E-10	7.98E-08	3.57E-10
40.00	2.69E-08	1.78E-10	1.82E-08	1.01E-10
45.00	6.88E-09	5.47E-11	4.44E-09	2.98E-11
50.00	1.87E-09	1.72E-11	1.15E-09	8.99E-12
60.00	1.60E-10	1.80E-12	9.06E-11	8.63E-13
70.00	1.56E-11	2.05E-13	8.08E-12	8.99E-14
80.00	1.64E-12	2.56E-14	7.78E-13	1.02E-14
90.00	1.87E-13	3.46E-15	8.15E-14	1.27E-15
100.00	2.35E-14	4.97E-16	9.35E-15	1.65E-16

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 0.0 DEGREES

		OOOOOOOE O3 NAUFICAL	MILES		
ANGLE OF V. A	A. SPECTRUM = 0.0 ABSORBED DOSE	DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CH2	$R_* r = 0.0 \text{ G/CM} 2$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AU N TTT A	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	5.41E-02	4.79E-06	5.21E-02	3.81E-06	319
3.00	1.80E-02	2.99E-06	1.70E-02	2.35E-06	9
5.00	3.06E-03	1.20E-06	2.81E-03	9.18E-07	
7.00	7.14E-04	4.97E-07	6.36E+04	3.73E-07	
10.00	1.10E-04	1.42E-07	9.40E-05	1.03E-07	
15.00	7.60E-06	2.00E-08	6.11E-06	1.37E-08	
20.00	7.52E-07	3.23E-09	5.69E-07	2.08E-09	
25.00	9.30E-08	5.81E-10	6.63E-08	3.54E-10	
30.00	1.35E-08	1.13E-10	9.09E-09	6.53E-11	
35.00	2.23E-09	2.34E-11	1.42E-09	1.28E-11	
40.00	4.09E-10	5.04E-12	2.46E-10	2.59E-12	
45.00	8. 10E-11	1. 12E- 12	4.61E-11	5.46E-13	
50.00	1.69E-11	2.60E-13	9.08E-12	1.20E-13	
50.00	8. 22E- 13	1.58E-14	3.95E-13	6.49E-15	
70.00	4.69E-14	1. 11E-15			
80.00	3. 13E-15	8.57E-17	2.01E-14	4.04E-16	
90.00	2.34E-16		1.19E-15	2.74E-17	
		7.01E-18	7.85E-17	1.97E-18	
100.00	1.87E-17	6.09E-19	5.53E-18	1.50E-19	

DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT RATE RATE RATE RATE R,T = 0.0 G/CM2 R,T = 15.0 G/CM2 R,F = 0.0 G/CM2 R,T = 15.0 G/CM2 SHIELD WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION R,S (G/CM2) REH REH PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 2.00 9.21E-02 6.93E-06 8.89E-02 5.51E-06 3.38E-06 5.00 4.79E-03 1.71E-06 4.39E-03 1.31E-06 7.00 1.08E-03 7.07E-07 9.65E-04 5.29E-07 15.00 1.08E-03 7.07E-07 9.65E-04 5.29E-07 15.00 1.09E-05 2.79E-08 8.78E-06 1.90E-08 1.45E-07 2.00C 1.06E-06 4.45E-09 8.01E-07 2.87E-09 3.000 1.06E-08 1.54E-10 1.25E-08 8.86E-11 3.500 3.04E-09 3.17E-11 1.25E-08 8.86E-11 3.500 3.04E-09 3.17E-11 1.93E-09 1.72E-11 45.00 1.09E-10 1.09E-10 3.39E-10 3.39E-12	PROTONS AS INCALTITUDE OF V. A.	A. SPACTRUM = 6.0	HIELD MATERIAL POLYET 0000000E 03 NAUTICAL DEGREES	HYLENE		
RATE R.T = 0.0 G/CH2 R.T = 15.0 G/CH2 R.T = 0.0 G/CH2 R.T = 15.0 G/CH2 SHIELD WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION R.S (G/CH2) REH REM REM REM REM PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 2.00 9.21E-02 6.93E-06 8.89E-02 5.51E-06 3.38E-06 5.00 4.79E-03 1.71E-06 4.39E-03 1.31E-06 7.00 1.08E-03 7.07E-07 9.65E-04 5.29E-07 15.00 1.08E-03 7.07E-07 9.65E-04 5.29E-07 15.00 1.09E-05 2.79E-08 8.78E-06 1.90E-08 1.90E-08 25.00 1.29E-07 7.95E-10 9.22E-08 4.83E-10 3.00 1.86E-08 1.54E-10 1.25E-08 8.86E-11 3.500 3.04E-09 3.17E-11 1.93E-09 1.72E-11 45.00 1.09E-10 1.51E-12 3.32E-10 3.49E-12				DOSE EQUIVALENT	DOSE EQUIVALENT	
SHIELD WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION R.S (G/CH2) REM PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 3.00 2.95E-02 4.31E-06 5.00 4.79E-03 1.71E-06 4.39E-03 1.31E-06 7.00 1.08E-03 7.07E-07 15.00 1.09E-05 2.79E-08 8.78E-06 1.90E-08 25.00 1.09E-07 30.00 1.06E-06 4.45E-09 8.01E-07 2.87E-09 30.00 1.86E-08 1.54E-10 1.25E-08 8.86E-11 40.00 5.54E-10 6.80E-12 3.32E-10 3.49E-12		RATE	RATE	RATE	RATE	
DEPTH ATTENUATION ATTENUATION ATTENUATION R.S (G/CH2) REM PER 1.00 DAY 9.21E-02 6.93E-06 5.00 4.79E-03 1.71E-06 1.08E-03 7.00 1.62E-04 1.08E-03 7.07E-07 15.00 1.09E-05 2.79E-08 8.78E-06 1.09E-07 15.00 1.09E-05 2.79E-08 8.78E-06 1.39E-04 1.45E-07 20.00 1.06E-06 4.45E-09 30.00 1.29E-07 7.95E-10 35.00 3.04E-09 3.17E-11 40.00 5.54E-10 3.32E-10 3.32E-10 3.49E-12		R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_*F = 0.0 \text{ G/CM}2$	R.T = 15.0 G/CM2	
R.S (G/CH2) REM PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 3.00 2.95E-02 4.31E-06 7.00 1.08E-03 7.07E-07 15.00 1.09E-05 2.79E-08 2.79E-08 2.79E-08 2.79E-08 3.00 1.06E-06 4.45E-09 3.00 1.06E-08 2.79E-10 3.00 1.06E-08 2.79E-10 3.00 1.06E-08 2.79E-10 3.00 1.06E-09 3.00 1.06E-09 3.00 1.06E-09 3.00 1.06E-08 3.17E-11 40.00 5.54E-10 6.80E-12 3.32E-10 3.49E-12	SHIELD	WITHOUT	WITHOUT	WITH	WITH	
PER 1.00 DAY PER 1	DEPTH	ATTENUATION	N CIT AU N STT A	ATTENUATION	ATTENUATION	
2.00 9.21E-02 6.93E-06 8.89E-02 5.51E-06 3.00 2.95E-02 4.31E-06 2.79E-02 3.38E-06 7.00 1.08E-03 7.07E-07 9.65E-04 5.29E-07 15.00 1.09E-05 2.79E-08 8.78E-06 1.90E-08 25.00 1.29E-07 7.95E-10 9.22E-08 4.83E-10 35.00 3.04E-09 3.17E-11 1.93E-09 1.72E-11 40.00 5.54E-10 1.09E-10 1.09E-10 3.49E-12	R,S (G/CM2)				REM	
3.00	2.00				PER 1.00 DAY	
7.00 1.08E-03 7.07E-07 9.65E-04 5.29E-07 15.00 1.09E-05 2.79E-08 8.78E-06 1.90E-08 25.00 1.29E-07 7.95E-10 9.22E-08 4.83E-10 35.00 3.04E-09 3.17E-11 1.93E-09 1.72E-11 45.00 1.09E-10 1.99E-10 3.32E-10 3.49E-12	3.00				5.51E-06	ω
7.00 1.08E-03 7.07E-07 9.65E-04 5.29E-07 10.00 1.62E-04 2.00E-07 1.39E-04 5.29E-07 15.00 1.09E-05 2.79E-08 8.78E-06 1.90E-08 25.00 1.06E-06 4.45E-09 8.01E-07 2.87E-09 30.00 1.86E-08 1.54E-10 9.22E-08 4.83E-10 35.00 3.04E-09 3.17E-11 1.93E-09 1.72E-11 40.00 5.54E-10 6.80E-12 3.32E-10 3.49E-12					3.38E-06	õ
10.00					1.31E-06	
15.00 1.09E-05 2.79E-08 8.78E-06 1.90E-08 20.00 1.06E-06 4.45E-09 8.01E-07 2.87E-09 30.00 1.86E-08 1.54E-10 9.22E-08 4.83E-10 35.00 3.04E-09 3.17E-11 1.93E-09 1.72E-11 40.00 5.54E-10 6.80E-12 3.32E-10 3.49E-12					5.29E-07	
20.00 1.06E-06 4.45E-09 8.01E-07 2.87E-09 25.00 1.29E-07 7.95E-10 9.22E-08 4.83E-10 30.00 1.86E-08 1.54E-10 1.25E-08 8.86E-11 40.00 5.54E-10 6.80E-12 3.32E-10 3.49E-12					1.45E-07	
25.00 1.29E-07 7.95E-10 9.22E-08 4.83E-10 35.00 3.04E-09 3.17E-11 1.93E-09 1.72E-11 40.00 5.54E-10 6.80E-12 3.32E-10 3.49E-12					1.90E-08	
30.00 1.86E-08 1.54E-10 9.22E-08 4.83E-10 35.00 3.04E-09 3.17E-11 1.93E-09 1.72E-11 40.00 5.54E-10 6.80E-12 3.32E-10 3.49E-12					2.87E-09	
35.00 3.04E-09 3.17E-11 1.25E-08 8.86E-11 40.00 5.54E-10 6.80E-12 3.32E-10 3.49E-12				9.22E-08		
40.00 5.54E-10 6.80E-12 1.93E-09 1.72E-11 45.00 1.09E-10 1.51E-13 3.32E-10 3.49E-12				1.25E-08		
45.00 1.09E-10 1.51E-12 3.32E-10 3.49E-12					-	
1.510.17				3.32E-10	-	
EA AA			1.51E-12	6.18E-11	7.34E-13	
50 00 2.20E-11 1.60F-13				1.22E-11		
20 00 5.25E-13 9 60E-15				5.25E-13		
1.47E-15 2.65E-14 5.32F-16					_	
90.00 4.11E-15 1.13E-16 1.56E-15 3.60E-17						
3.05E-16 9.20E-18 1.02E-16 2.50D.40			9.20E-18			
100.00 2.43E-17 7.97E-19 7.18E-18 2.58E-18 1.96E-19	100.00	2. 43E- 17	7.97E-19			

	A. SPECTRUM = 6.0	IELD MATERIAL COPPER 000000E 03 NAUTICAL DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUETION	ATTENUATION	NCITAUNATTA	
R,S (G/CM2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	
2.00	1.90E-01	6.84E-06	1.87E-01	5.50E-06	ω
3.00	8.03E-02	5.04E-06	7.84E-02	4.02E-06	321
5.00	2.02E-02	2.77E-06	1.94E-02	2. 18E-06	
7.00	6.46E-03	1.55E-06	6.09E-03	1.20E-06	
10.00	1.50E-03	6.66E-07	1.38E-03	5.05E-07	
15.00	1.95E-04	1.74E-07	1.72E-04	1.27E-07	
20.00	3.26E-05	4.86E-08	2.78E-05	3.44E-08	
25.00	6.54E-06	1.44E-08	5.38E-06	9.83E-09	
30.00	1.49E-06	4.48E-09	1.18E-06	2.96E-09	
35.00	3.72E-07	1.46E-09	2.86E-07	9.30E-10	
40.00	1.00E-07	4.94E-10	7.43E-08	3.04E-10	
45.00	2.88E-08	1.72E-10	2.06E-08	1.02E-10	
50.00	8.76E-09	6.17E-11	6.04E-09	3.54E-11	
60.00	9.22E-10	8.34E-12	5.92E-10	4.47E-12	
70.00	1. 12E-10	1. 19E-12	6.72E-11	5.96E-13	
80.00	1.49E-11	1.81E-13	8.33E-12	8.45E-14	
90.00	2. 10 E- 12	2.94E-14	1.10E-12	1.28E-14	
100.00	3.13E-13	5.10B-15	1.52E-13	2.07E-15	

2225242 12 74					
		IELD MATERIAL COPPER 000000E 03 NAUTICAL			
ANGLE OF V. A.		DEGREES	HITE2		
ANGLE OF V. A.	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
		Jour Pager August	DODE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM} 2$	R.T = 15.0 G/CM2	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CH2)	REH	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	3.99E-01	9.94E-06	3.94E-01	7.98E-06	322
3.00	1.61E-01	7.30E-06	1.57E-01	5.82E-06	12
5.00	3.82E-02	4.00E-06	3.67E-02	3.14E-06	
7.00	1.18E-02	2.23E-06	1.11E-02	1.73E-06	
10.00	2.64E-03	9.50E-07	2.44E-03	7.20E-07	
15.00	3.30E-04	2.45E-07	2.93E-04	1.80E-07	
20.00	5.40E-05	6.82E-08	4.62E-05	4.82E-08	
25.00	1.06E-05	2.01E-08	8.76E-06	1.37E-08	
30.00	2.39E-06	6.20E-09	1.90E-06	4.09E-09	
35.00	5.91E-07	2.01E-09	4.53E-07	1.28E-09	
40.00	1.58E-07	6.77E-10	1.17E-07	4. 16 E- 10	
45.00	4.49E-08	2.35E-10	3.21E-08	1.40E-10	
50.00	1.35E-08	8.4CE-11	9.33E-09	4.81E-11	
60.00	1 417-00	4 435 44	0.00= 40	4.01E-11	

1.13E-11

1.61E-12

2.43E-13

3.93E-14

6.79E-15

9.02E-10

1.01E-10

1.25E-11

1.64E-12

2.26E-13

6.05E-12

8.04E-13

1.13E-13

1.71E-14

2.75E-15

60.00

70.00

80.00

90.00

100.00

1.41E-09

1.69E-10

2.23E-11

3. 13E-12

4.65E-13

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL HILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE UP V. A.	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_{r}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/3M2}$	R,F = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2 44	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	4.32E-02	2.17E-06	4.23E-02	1.73E-06	3 23
3.00	1.70E-02	1.52E-06	1.64E-02	1.21E-06	W
5.00	3.79E-03	7.65E-07	3.57E-03	5.95E-07	
7.00	1.10E-03	3.92E-07	1.01E-03	3.00E-07	
10.00	2.26E-04	1.49E-07	2.02E-04	1.11E-07	
15.00	2.44E-05	3.26E-08	2.07E-05	2.32E-08	
20.00	3.48E-06	7.73E-09	2.82E-06	5.26E-09	
25.00	6.08E-07	1.97E-09	4.70E-07	1.28E-09	
30.00	1.21E-07	5.36E-10	8.93E-08	3.34E-10	
35.00	2.67E-08	1.53E-10	1.89E-08	9.14E-11	
40.00	6.42E-09	4.58E-11	4.34E-09	2.61E-11	
45.00	1.65E-09	1.41E-11	1.07E-09	7.70E-12	
50.00	4.52E-10	4.45E-12	2.79E-10	2.33E-12	
60.00	3.92E-11	4.69E-13	2.22E-11	2.25E-13	
70.00	3.83E-12	5.36E-14	1.99E-12	2.35E-14	
80.00	4.06E-13	6.73E-15	1.93F-13	2.70E-15	
90.00	4.67E-14	9.16E-16	2.03E-14	3.35E-16	
100.00	5.90E-15	1.32E-16	2.35E-15	4.39E-17	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

ANGLE OF V. A.	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
SHIELD	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION		
R,S (G/CH2)	REM	REM	REM	NCITAUNATIA	
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	REM	
	8.30E-02	3.14E-06		PER 1.00 DAY	
3.00	3.12E-02	2.20E-06	8.14E-02	2.51E-06	ω
5.00	6.60E-03	1.10E-06	3.02E-02	1.74E-06	324
7.00	1.85E-03		6.24E-03	8.56E-07	
10.00	3.69E-04	5.61E-07	1.71E-03	4.29E-07	
15.00	3.85E-05	2.12E-07	3.30E-04	1.58E-07	
20.00	5.37E-06	4.58E-08	3.27E-05		
25.00	9.23E-07	1.08E-08	4.35E-06	3.26E-08	
30.00		2.73E-09	7.14E-07	7.33E-09	
35.00	1.81E-07	7.37E-10	1.34E-07	1.77E-09	
40.00	3.96E-08	2.10E-10	2.80E-08	4.58E-10	
	9.42E-09	6.24E-11		1.25E-10	
45.00	2.41E-09	1.92E-11	6.37E-09	3.55E-11	
50.00	6.54E-10	6.03E-12	1.56E-09	1.04E-11	
60.00	5.61E-11	6.32E-13	4.04E-10	3. 15E-12	
70.00	5.45E-12		3.17E-11	3.02E-13	
80.00	5.74E-13	7.19E-14	2.83E-12	3. 15E-14	
90.00	6.56E-14	8.96E-15	2.73E-13		
100.00		1.21E-15	2.86E-14	3.59E-15	
	8.24E-15	1.74E-16	3.28E-15	4.44E-16	
			3.201-13	5.79E-17	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DECREES

ANGLE OF V. A	$\bullet SPECTRUM = 3.0000$	0000E 01 DEGREES			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CH2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.89E-02	1.68E-06	1.82E-02	1.34E-06	w
3.00	6.30E-03	1.05E-06	5.96E-03	8.22E-07	325
5.00	1.07E-03	4.19E-07	9.84E-04	3.22E-07	
7.00	2.50E-04	1.74E-07	2.23E-04	1.30E-07	
10.00	3.85E-05	4.97E-08	3.29E-05	3.60E-08	
15.00	2.66E-06	7.01E-09	2.14E-06		
20.00	2.63E-07	1.13E-09	1.99E-07	4.78E-09	
25.00	3.26E-08	2.03E-10	2.32E-08	7.29E-10	
30.00	4.72E-09	3.97E-11	3. 18E-09	1.24E-10	
35.00	7.82E-10	8.20E-12		2.29E-11	
40.00	1.43E-10	1.76E-12	4.98E-10	4.47E-12	
45.00	2.84E-11	3.93E-13	8.62E-11	9.08E-13	
50.00	5.91E-12		1.61E-11	1.91E-13	
60.00	2.88E-13	9.10E-14	3. 18E-12	4.19E-14	
70.00	1.64E-14	5.55E-15	1.38E-13	2.27E-15	
80.00		3.91E-16	7.04E-15	1.41E-16	
90.00	1. 10E-15	3.00E-17	4.17E-16	9.59E-18	
100.00	8.19E-17	2.46E-18	2.75E-17	6.90E-19	
100.00	6.55E-18	2.13E-19	1.94E-18	5.26E-20	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DECERTS

ANGLE OF V. A.	DOSE EQUIVALENT	000E 01 DEGREES DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	$R_*T = 0.0 \text{ G/CM}2$	E.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RES	REM	REM	REM	
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
3.00	3. 23E-02	2.43E-06	3.11E-02	1.93E-06	ω
5.00	1.03E-02	1.51E-06	9.78E-03	1.18E-06	326
7.00	1.68E-03	6.00E-07	1.54E-03	4.60E-07	
10.00	3.79E-04	2.48E-07	3.38E-04	1.85E-07	
15.00	5.69E-05	7.00E-08	4.87E-05	5.07E-08	
20.00	3.83E-06	9.77E-09	3.07E-06	6.65E-09	
25.00	3.72E-07	1.56E-09	2.81E-07	1.00E-09	
30.00	4.53E-08	2.78E-10	3.23E-08	1.69E-10	
35.00	6.50E-09	5.40E-11	4.37E-09	3. 10E-11	
40.00	1.06E-09	1.11E-11	6.77E-10	6.04E-12	
45.00	1.94E-10	2.38E-12	1.16E-10	1.22E-12	
	3.81E-11	5.29E-13	2.17E-11	2.57E-13	
50.00	7.93E-12	1.22E-13	4.26E-12	5.60E-14	
60.00	3.83E-13	7.38E-15	1.84E-13	3.02E-15	
70.00	2.17E-14	5.16E-16	9.27E-15	1.87E-16	
80.00	1.44E-15	3.95E-17	5.47E-16		
90.00	1.07E-16	3.22E-18	3.59E-17	1.26E-17	
100.00	8.52E-18	2.79E-19	2.52E-18	9.05E-19	
		• •	2132110	6.87E-20	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 04 DEGREES

ANGLE OF V. A	ABSORBED DOSE	DOODE O1 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	PAD 1 00 PAG	RAD	RAD	RAD	
2.00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
3.00	6.65E-02	2.40E-06	6.56E-02	1.93E-06	ω
	2.81E-02	1.76E-06	2.75E-02	1. 41E-06	327
5.00	7.08E-03	9.72E-07	6.79E-03	7.64E-07	
7.00	2.26E-03	5.43E-07	2.13E-03	4.21E-07	
10.00	5.26E-04	2.33E-07	4.84E-04	1.77E-07	
15.00	6.81E-05	6.08E-08	6.04E-05	4.46E-08	
20.00	1.14E-05	1.70E-08	9.75E-06	1. 21E-08	
25.00	2.29E-06	5.04E-09	1.88E-06	3.44E-09	
30.00	5.22E-07	1.57E-09	4.14E-07	1.03E-09	
35.00	1.30E-07	5.11E-10	1.00E-07	3.26E-10	
40.00	3.52E-08	1.73E-10	2.60E-08		
45.00	1.01E-08	6.04E-11	7.22E-09	1.06E-10	
50.00	3.07E-09	2.16E-11	2.12E-09	3.59E-11	
60.00	3.23E-10	2.92E-12	2.07E-10	1.24E-11	
70.00	3.92E-11	4.18E-13	2.07E-10 2.35E-11	1.56E-12	
80.00	5.218-12	6.34E-14	2.92E-12	2.09E-13	
90.00	7.35E-13	1.03E-14		2.96E-14	
100.00	1.10E-13	1.79E-15	3.84E-13	4.50E-15	
		10/20-13	5.33E-14	7.27E-16	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 3.0000000E 01 DEGREES

WAGEE OF A. W.	SPECTRUM = 3.0000	000E 01 DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM2}$	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REH	REM	REM	REM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	1.40E-01	3.48E-06	1.38E-01	2.80E-06	(4)
3.00	5.62E-02	2.56E-06	5.51E-02		328
5.00	1.34E-02	1.40E-06	1.29E-02	2.04E-06	ω
7.00	4.13E-03	7.80E-07	3.90E-03	1. 10 E-06	
10.00	9.25E-04	3.33E-07		6.04E-07	
15.00	1.16E-04	8.59E-08	8.53E-04	2.52E-07	
20.00	1.89E-05	2.39E-08	1.03E-04	6.29E-08	
25.00	3.72E-06	7.02E-09	1.62E-05	1.69E-08	
30.00	8.37E-07	2. 17E-09	3.07E-06	4.79E-09	
35.00	2.07E-07		6.65E-07	1.43E-09	
40.00	5.52E-08	7.03E-10	1.59E-07	4.48E-10	
45.00	1.57E-08	2.37E-10	4.09E-08	1.46E-10	
50.00		8.24E-11	1.12E-08	4.89E-11	
	4.74E-09	2.94E-11	3.27E-09	1.69E-11	
60.00	4.92E-10	3.96E-12	3.16E-10	2.12E-12	
70.00	5.92E-11	5.64E-13	3.55E-11	2.81E-13	
80.00	7.82E-12	8.52E-14	4.38E-12	3.97E-14	
90.00	1.10E-12	1.38E-14	5.73E-13	6.00E-15	
100.00	1.63E-13	2.38E-15	7.91E-14	9.65E-16	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

	SPECTRUM = 6.0000 ABSORBED DOSE	000E 01 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	ABSORBED DOSE	ADSURBED DJSE	EBSURBED DUSE	RBSORBED DOSE	
	RATE	RATE	RATE	RATE	
	$R_*T = 0.0 G/CM2$	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	
2.00	2.34E-02	1.17E-06	2.29E-02	9.40E-07	329
3.00	9.21E-03	8.25E-07	8.90E-03	6.54E-07	9
5.00	2.05E-03	4.15E-07	1.94E-03	3.23E-07	
7.00	5.96E-04	2.13E-07	5.49E-04	1.62E-07	
10.00	1.23E-04	8.09E-08	1.10E-04	6.02E-08	
15.00	1.32E-05	1.77E-08	1.12E-05	1.26E-08	
20.00	1.89E-06	4.19E-09	1.53E~06	2.85E-09	
25.00	3.30E-07	1.07E-09	2.55E-07	6.95E-10	
30.00	6.55E-08	2.90E-10	4.84E-08	1.81E-10	
35.00	1.45E-08	8.32E-11	1.02E-08	4.95E-11	
40.00	3.48E-09	2.48E-11	2.35E-09	1.42E-11	
45.00	8.96E-10	7.65E-12	5.79E-10	4.18E-12	
50.00	2.45E-10	2.41E-12	1.52E-10	1.26E-12	
60.00	2.12E-11	2.54E-13	1.20E-11	1.22E-13	
70.00	2.08E-12	2.91E-14	1.08E-12	1.28E-14	
80.00	2.20E-13	3.65E-15	1.05E-13	1.46E-15	
90.00	2.53E-14	4.97E-16	1.10E-14	1.82E-16	
100.00	3.20E-15	7.15E-17	1.27E-15	2.38E-17	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 G/CM2$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	REM
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	4.50E-02	1.70E-06	4.42E-02	1.36E-06
3.00	1.69E-02	1.19E-06	1.64E-02	9.46E-07
5.00	3.58E-03	5.96E-07	3.38E-03	4.64E-07
7.00	1.00E-03	3.04E-07	9.27E-04	2.32E-07
10.00	2.00E-04	1.15E-07	1.79E-04	8.54E-08
15.00	2.08E-05	2.48E-08	1.77E-05	1.76E-08
20.00	2.91E-06	5.85E-09	2.36E-06	3.97E-09
25.00	5.00E-07	1.48E-09	3.87E-07	9.62E-10
30.00	9.82E-08	3.99E-10	7.25E-08	2.49E-10
35.00	2.15E-08	1.14E-10	1.52E-08	6.77E-11
40.00	5.11E-09	3.38E-11	3.45E-09	1.93E-11
45.00	1.31E-09	1.04E-11	8.43E-10	5.66E-12
50.00	3.54E-10	3.27E-12	2.19E-10	1.71E-12
60.00	3.04E-11	3.43E-13	1.72E-11	1.64E-13
70.00	2.96E-12	3.90E-14	1.53E-12	1. 71E-14
80.00	3.11E-13	4.86E-15	1.48E-13	1.95E-15
90.00	3.56E-14	6.58E-16	1.55E-14	2.41E-16
100.00	4.47E-15	9.45E-17	1.78E-15	3. 14E-17

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PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES

ALTITUDE OF V.	A. SPECTRUM = 6.0	OOOOOOE OS NAUTICAL	HILES	
ANGLE OF V. A.	SPECTRUM = 6.0000 ABSORBED DOSE	OOOE O1 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	RATE	RATE	RATE	RATE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_*P = 0.0 G/CM2$	$R_T = 15.0 \text{ G/CM2}$
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
n, 5 (G/CHZ)	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	1.03E-02	9.10E-07	9.89E-03	7.24E-07
3.00	3.42E-03	5.67E-07	3.23E-03	4.46E-07
5.00	5.82E-04	2.27E-07	5.34E-04	1.74E-07
	1. 36E-04	9.44E-08	1.21E-04	7.07E-08
7.00	2.09E-05	2.69E-08	1.79E-05	1.95E-08
10.00	1.44E-06	3.80E-09	1.16E-06	2.59E-09
15.00	1.43E-07	6.13E-10	1.08E-07	3,95E-10
20.00	-	1. 10E- 10	1.26E-08	6.72E-11
25.00	1.77E-08	2.15E-11	1.738-09	1.24E-11
30.00	2.56E-09	4.45E-12	2.70E-10	2.42E-12
35.00	4.24E-10	9.57E-13	4.67E-11	4.92E-13
40.00	7.77E-11	2.13E-13	8.74E-12	1.04E-13
45.00	1.54E-11	4.94E-14	1.72E-12	2.27E-14
50.00	3.21E-12		7.51E-14	1.23E-15
60.00	1.56E-13	3.01E-15	3.82E-15	7.67E-17
70.00	8.90E-15	2.12E-16	2.26E-16	5.20E-18
80.00	5.96E-16	1.63E-17	1.49E-17	3.74E-19
90.00	4.44E-17	1.33E-18	1.05E-18	2.85E-20
100.00	3.55E-18	1.16E-19	1.035-10	2.002

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

RATE RATE	ANGLE OF V. A	. SPECTRUM = 6.0000	000E 01 DEGREES	utre?		
R.T = 0.0 G/CH2 B.T = 15.0 G/CH2 R.T = 0.0 G/CH2 R.T = 15.0 G/CM2 SHIELD WITHOUT WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION R.S (G/CH2) REM REM REM REM REM REM 2.00 1.75E-02 1.32E-06 1.69E-02 1.05E-06 3.00 5.60E-03 8.18E-07 5.30E-03 6.42E-07 5.00 9.09E-04 3.25E-07 8.34E-04 2.49E-07 7.00 2.06E-04 1.34E-07 1.83E-04 1.00E-07 10.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 20.00 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 35.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 50.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.05E-10 1.29E-12 6.31E-11 1.17E-11 1.39E-13 50.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.31E-16 5.03E-15 1.01E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
SHIELD WITHOUT WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION R.S (G/CM2) REM REM REM REM REM PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 2.00 1.75E-02 1.32E-06 1.69E-02 1.05E-06 3.00 5.60E-03 8.18E-07 5.30E-03 6.42E-07 5.00 9.09E-04 3.25E-07 8.34E-04 2.49E-07 7.00 2.06E-04 1.34E-07 1.83E-04 1.00E-07 10.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 20.00 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 30.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		RATE	RATE	RATE	RATE	
DEPTH ATTENUATION ATTENUATION ATTENUATION R,S (G/CM2) REM PER 1.00 DAY 1.05E-06 6.42E-07 1.32E-07 1.52E-08 3.4E-04 1.57E-08 3.04E-14 1.64E-15 1.01E-16 6.84E-18 4.91E-19		R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
R.S (G/CM2) REM PER 1.00 DAY 1.75E-02 PER 1.00 DAY 1.05E-06 3.00 5.60E-03 8.18E-07 5.30E-03 6.42E-07 7.00 2.06E-04 1.34E-07 1.83E-04 1.00E-07 10.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 20.00 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 30.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18	SHIELD	WITHOUT	WITHOUT	WITH	WITH	
PER 1.00 DAY 2.00 DAY 1.75E-02 1.32E-06 1.69E-02 1.05E-06 3.00 5.60E-03 8.18E-07 5.30E-03 6.42E-07 7.00 2.06E-04 1.34E-07 1.83E-04 2.49E-07 7.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 20.00 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 30.00 3.52E-09 2.93E-11 2.37E-09 1.668E-11 35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19	DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
2.00 1.75E-02 1.32E-06 1.69E-02 1.00 DAY 3.00 5.60E-03 8.18E-07 5.30E-03 6.42E-07 5.00 9.09E-04 3.25E-07 8.34E-04 2.49E-07 7.00 2.06E-04 1.34E-07 1.83E-04 1.00E-07 10.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 20.00 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 30.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19	R,S (G/CM2)	REM	REM	REM	DPM	
2.00		PER 1.00 DAY	PER 1.00 DAY			
3.00 5.60E-03 8.18E-07 5.30E-03 6.42E-07 7.00 9.09E-04 3.25E-07 8.34E-04 2.49E-07 7.00 2.06E-04 1.34E-07 1.83E-04 1.00E-07 10.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 2.000 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 30.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 70.00 1.18E-14 2.80E-16 5.03E-15 1.04E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		1.75E-02	1.32E-06			w
5.00 9.09E-04 3.25E-07 8.34E-04 2.49E-07 7.00 2.06E-04 1.34E-07 1.83E-04 1.00E-07 10.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 20.00 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 30.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19 </td <td>_</td> <td>5.60E-03</td> <td></td> <td></td> <td></td> <td>32</td>	_	5.60E-03				32
7.00 2.06E-04 1.34E-07 10.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 20.00 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 30.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 3.28E-12 40.00 1.05E-10 1.29E-12 40.00 1.05E-10 1.29E-12 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17		9.09E-04	3.25E-07			
10.00 3.09E-05 3.80E-08 2.64E-05 2.75E-08 15.00 2.07E-06 5.30E-09 1.67E-06 3.61E-09 20.00 2.02E-07 8.45E-10 1.52E-07 5.44E-10 25.00 2.46E-08 1.51E-10 1.75E-08 9.18E-11 30.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		2.06E-04	1.34E-07			
15.00		3.09E-05	3.80E-08			
20.00		2.07E-06	5.30E-09			
25.00		2.02E-07	8.45E-10			
30.00 3.52E-09 2.93E-11 2.37E-09 1.68E-11 35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		2.46E-08				
35.00 5.77E-10 6.02E-12 3.67E-10 3.28E-12 40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		3.52E-09	2.93E-11			
40.00 1.05E-10 1.29E-12 6.31E-11 6.63E-13 45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		5.77E-10	6.02E-12			
45.00 2.07E-11 2.87E-13 1.17E-11 1.39E-13 50.00 4.30E-12 6.61E-14 2.31E-12 3.04E-14 60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		1.05E-10	1.29E-12			
50.00		2.07E-11	2.87E-13			
60.00 2.08E-13 4.00E-15 9.97E-14 1.64E-15 70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		4.30E-12	6.61E-14			
70.00 1.18E-14 2.80E-16 5.03E-15 1.01E-16 80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19		2.08E-13	4.00E-15			
80.00 7.81E-16 2.14E-17 2.96E-16 6.84E-18 90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19	70.00	1.18E-14				
90.00 5.80E-17 1.75E-18 1.94E-17 4.91E-19	80.00	7.81E-16				
100 00 4 607 40	90.00	5.80E-17				
	100.00	4.62E-18				

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ABSORBED DOSE	000E 01 DEGREES ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
RATE	RATE	RATE	RATE	
R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
WITHOUT	WITHOUT	WITH	WITH	
ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
RAD	RAD	RAD	RAD	
			PER 1.00 DAY	
		3.56E-02	1.043-06	333
		1.49E-02	7.64E-07	ຜ
	5.27E-07	3.68E-03	4.14E-07	
	2.94E-07	1.16E-03	2.28E-07	
2.85E-04	1.26E-07	2.62E-04		
3.69E-05	3.30E-08			
6.19E-06	9.23E-09			
1.24E-06	2.73E-09			
2.83E-07				
7.07E-08				
J. 35E- 14	9./12-16	2.89E-14	3.94E~16	
	RTE RTE RTE RTE RT = 0.0 G/CM2 WITHOUT ATTENUATION RAD PER 1.00 DAY 3.61E-02 1.52E-02 3.84E-03 1.23E-03 2.85E-04 3.69E-05 6.19E-06 1.24E-06	RTE RATE R.T = 0.0 G/CM2 R.T = 15.0 G/CM2 WITHOUT WITHOUT ATTENUATION ATTENUATION RAD PER 1.00 DAY PER 1.00 DAY 3.61E-02 1.30E-06 1.52E-02 9.57E-07 3.84E-03 5.27E-07 1.23E-03 2.94E-07 2.85E-04 1.26E-07 3.69E-05 3.30E-08 6.19E-06 9.23E-09 1.24E-06 2.73E-09 2.83E-07 8.50E-10 7.07E-08 9.37E-11 5.48E-09 3.27E-11 1.66E-09 1.17E-11 1.75E-10 2.27E-13 2.83E-12 3.44E-14 3.99E-13 3.44E-14	RITE RATE RATE RAD PER 1.00 DAY 3.61E-02 1.30E-06 1.30E-06 3.56E-02 1.52E-02 9.57E-07 1.49E-02 3.84E-03 5.27E-07 3.68E-03 1.23E-03 2.85E-04 3.69E-05 3.30E-08 3.27E-05 6.19E-06 2.83E-07 8.50E-10 2.25E-07 7.07E-08 1.91E-08 9.37E-11 3.91E-09 1.66E-09 1.17E-11 1.15E-09 1.75E-10 2.27E-13 3.99E-13 5.60E-15 2.08E-13	ABSORBED DOSE RITE RATE RAT

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 6.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 6.0000	000E 01 DEGREES	HILES		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R,T = 0.0 G/CH2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
2 00	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	
2.00	7.57E-02	1.89E-06	7.49E-02	1.52E-06	334
3.00	3.05E-02	1.39E-06	2.98E-02	1.11E-06	4
5.00	7.25E-03	7.59E-07	6.97E-03	5.97E-07	
7.00	2.24E-03	4.23E-07	2.12E-03	3.28E-07	
10.00	5.02E-04	1.80E-07	4.62E-04	1.37E-07	
15.00	6.27E-05	4.66E-08	5.56E-05	3.41E-08	
20.00	1.03E-05	1.29E-08	8.77E-06	9.16E-09	
25.00	2.02E-06	3.81E-09	1.66E-06	2.60E-09	
30.00	4.54E-07	1.18E-09	3.61E-07	7.76E+10	
35.00	1.12E-07	3.81E-10	8.60E-08		
40.00	2.99E-08	1.28E-10	2.22E-08	2.432-10	
45.00	8.52E-09	4.47E-11	6.09E-09	7.90E-11	
50.00	2.57E-09	1.59E-11		2.65E-11	
60.00	2.67E-10	2. 15E-12	1.77E-09	9.14E-12	
70.00	3. 21E-11		1.71E-10	1.15E-12	
80.00	4.24E-12	3.06E-13	1.928-11	1.53E-13	
90.00		4.62E-14	2.37E-12	2.15E-14	
100.00	5.95E-13	7.48E-15	3.11E-13	3.25E-15	
100.00	8.83E-14	1.29E-15	4.29E-14	5.24E-16	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	ADSORDED DOSE	ADSONDED DOSE	ADSORBED DOSE	RBSORBED DOSE
	RATE	RATE	RATE	PATE
	$R_{\bullet}T = 0.0 \text{ G/CM}2$	$R_{\bullet}T = 15.0 \text{ G/CM}2$	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	N CITAUN STT A	ATTENUATION	ATTENUATION
R,S (G/CM2)	RAD	RAD	RAD	RAD
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY
2.00	1.92E-02	9.60E-07	1.88E-02	7.69E-07
3.00	7.53E-03	6.75E-07	7.28E-03	5.35E-07
5.00	1.68E-03	3.39E-07	1.58E-03	2.64E-07
7.00	4.87E-04	1.74E-07	4.49E-04	1.33E-07
10.00	1.00E-04	6.62E-08	8.96E-05	4.92E-08
15.00	1.08E-05	1.44E-08	9.17E-06	1.03E-08
20.00	1.54E-06	3.43E-09	1.25E-06	2.33E-09
25.00	2.70E-07	8.74E-10	2.08E-07	5.69E-10
30.00	5.36E-08	2.38E-10	3.96E-08	1.48E-10
35.00	1.18E-08	6.80E-11	8.36E-09	4.05E-11
40.00	2.84E-09	2.03E-11	1.92E-09	1. 16 E-11
45.00	7.33E-10	6.26E-12	4.74E-10	3.42E-12
50.00	2.00E-10	1.97E-12	1.24E-10	1.03E-12
60.00	1.74E-11	2.08E-13	9.83E-12	9.96E-14
70.00	1.70E-12	2.38E-14	8.82E-13	1.04E-14
80.00	1.80E-13	2.99E-15	8.55E-14	1.20E-15
90.00	2.07E-14	4.06E-16	9.02E-15	1.49E-16
100.00	2.62E-15	5.85E-17	1.04E-15	1.95E-17

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM
ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES
ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	SPECTRUM = 9.0000 DOSE EQUIVALENT		DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	$R_T = 0.0 \text{ G/CM} 2$	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNATIA	
R,S (G/CM2)	REM PER 1.00 DAY	REM PER 1.00 DAY	REM PER 1.00 DAY	REM	
2.00	3.68E-02	1.39E-06	3.61E-02	PER 1.00 DAY	
3.00	1.38E-02	9.76E-07	1.34E-02	1.11E-06	336
5.00	2.93E-03	4.88E-07	2.77E-03	7.73E-07	0,
7.00	8.21E-04	2.49E-07	7.58E-04	3.79E-07	
10.00	1.64E-04	9.40E-08		1.90E-07	
15.00	1.70E-05	2.03E-08	1.46E-04 1.45E-05	6.99E-08	
20.00	2.38E-06	4.78E-09		1.44E-08	
25.00	4.09E-07	1.21E-09	1.93E-06	3.25E-09	
30.00	8.03E-08	3.27E-10	3.16E-07	7.87E-10	
35.00	1.75E-08	9.31E-11	5.93E-08	2.03E-10	
40.00	4.18E-09	2.77E-11	1.24E-08	5.54E-11	
45.00	1.07E-09		2.82E-09	1.58E-11	
50.00	2.90E-10	8.50E-12	6.90E-10	4.63E-12	
60.00		2.67E-12	1.79E-10	1.40E-12	
70.00	2.49E-11	2.80E-13	1.41E-11	1.34E-13	
	2. 42E-12	3.19E-14	1.25E-12	1.40E-14	
8 0. 00	2.54E-13	3.98E-15	1. 21E-13	1.59E-15	
90.00	2.91E-14	5.39E-16	1.27E-14	1.97E-16	
100.00	3.66E-15	7.73E-17	1.45E-15	2.57E-17	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE

ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES

ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	RATE	RATE	RATE	RATE
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	$R_*T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	N CIT AU N T T A	ATTENUATION	ATTENUATION
R,S (G/CM2)	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY	RAD PER 1.00 DAY
2.00	8.40E-03	7.44E-07	8.09E-03	5.92E-07
3.00	2.79E-03	4.64E-07	2.64E-03	3.65E-07
5.00	4.76E-04	1.86E-07	4.36E-04	1.43E-07
7.00	1. 11E-04	7.72E-08	9.88E-05	5.78E-08
10.00	1.71E-05	2.20E-08	1.46E-05	1.60E-08
15,00	1. 18 E-06	3.11E-09	9.49E-07	2.12E-09
20.00	1.17E-07	5.01E-10	8.83E-08	3.23E-10
25.00	1.44E-08	9.02E-11	1.03E-08	5.49E-11
30.00	2.09E-09	1.76E-11	1.41E-09	1.01E-11
35.00	3.47E-10	3.64E-12	2.21E-10	1.98E-12
40.00	6.36E-11	7.82E-13	3.82E-11	4.03E-13
45.00	1.26E-11	1.74E-13	7.15E-12	8.48E-14
50.00	2.62E-12	4.04E-14	1.41E-12	1.86E-14
60.00	1.28E-13	2.46E-15	6.14E-14	1.01E-15
70.00	7.28E-15	1.73E-16	3.12E-15	6.27E-17
80.00	4.87E-16	1.33E-17	1.85E-16	4.25E-18
90.00	3.63E-17	1.09E-18	1.22E-17	3.06E-19
100.00	2.90E-18	9.46E-20	8.58E-19	2.33E-20

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES

100.00

3.78E-18

ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT RATE RATE RATE RATE $R_{\bullet}T = 0.0 \text{ G/CM}2$ R.T = 15.0 G/CM2 $R_T = 0.0 \text{ G/CM}^2$ R.T = 15.0 G/CM2SHIELD WITHOUT WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUATION R.S (G/CM2) REM REM REM REM PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 2.00 1.43E-02 1.08E-06 1.38E-02 8.56E-07 3.00 4.58E-03 6.69E-07 4.34E-03 5.25E-07 5.00 7.43E-04 2.66E-07 6.82E-04 2.04E-07 7.00 1.68E-04 1.10E-07 1.50E-04 8.22E-08 10.00 2.52E-05 3.10E-08 2.16E-05 2.25E-08 15.00 1.70E-06 4.33E-09 1.36E-06 2.95E-09 20.00 1.65E-07 6.91E-10 1.24E-07 4.45E-10 25.00 2.01E-08 1.23E-10 1.43E-08 7.50E-11 30.00 2.88E-09 2.39E-11 1.94E-09 1.38E-11 35.00 4.72E-10 4.93E-12 3.00E-10 2.68E-12 40.00 8.60E-11 1.06E-12 5.16E-11 5.42E-13 45.00 1.69E-11 2.34E-13 9.60E-12 1. 14E-13 50.00 3.51E-12 5.41E-14 1.89E-12 2.49E-14 60.00 1.70E-13 3.27E-15 8.16E-14 1.34E-15 70.00 9.61E-15 2.29E-16 4.11E-15 8.27E-17 80.00 1.75E-17 6.39E-16 2.42E-16 5.59E-18 90.00 4.74E-17 1.43E-18 1.59E-17 4.01E-19

1.24E-19

1.12E-18

3.05E-20

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES

ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES ABSORBED DOSE ABSORBED DOSE ABSORBED DOSE ABSORBED DOSE RATE RATE RATE RATE $R_T = 0.0 G/CM2$ R.T = 15.0 G/CM2 $R_*T = 0.0 G/2M2$ $R.T = 15.0 \text{ G/CM}^2$ SHIELD WITHOUT WITHOUT WITH WITH ATTENUATION DEPTH ATTENUATION ATTENUATION ATTENUATION R.S (G/CM2) RAD RAD RAD RAD PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY PER 1.00 DAY 2.00 339 2.95E-02 1.06E-06 2.91E-02 8.54E-07 3.00 1.25E-02 6.25E-07 7.82E-07 1.22E-02 5.00 3.14E-03 4.31E-07 3.01E-03 3.39E-07 7.00 2.41E-07 1.00E-03 9.46E-04 1.87E-07 10.00 2.33E-04 7.84E-08 1.03E-07 2.15E-04 15.00 3.02E-05 2.70E-08 2.68E-05 1.98E-08 20.00 5.06E-06 7.55E-09 4.32E-06 5.342-09 25.00 8.36E-07 1.01E-06 2.23E-09 1.53E-09 30.00 2.31E-07 6.95E-10 1.84E-07 4.59E-10 35.00 5.78E-08 2.26E-10 4.43E-08 1.44E-10 40.00 1.56E-08 7.67E-11 1.15E-08 4.722-11 45.00 4.48E-09 2.68E-11 3.20E-09 1.59E-11 50.00 1.36E-09 9.58E-12 9.38E-10 5.50E-12 60.00 1.43E-10 1.29E-12 9.20E-11 6.94E-13 70.00 1.74E-11 1.85E-13 1.04E-11 9.26E-14 80.00 2.31E-12 2.81E-14 1.29E-12 1.31E-14 90.00 3. 26E-13 4.58E-15 1.70E-13 2.00E-15 100.00 4.86E-14

7.94E-16

2.36E-14

3.23E-16

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER ALTITUDE OF V. A. SPECTRUM = 6.0000000E 03 NAUTICAL MILES ANGLE OF V. A. SPECTRUM = 9.0000000E 01 DEGREES

ANGLE OF V. A.	. SPECTRUM = 9.0000	000E 01 DEGREES			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	RATE	RATE	RATE	RATE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	DEM	
	PER 1.00 DAY	PER 1.00 DAY	PER 1.00 DAY	REM	
2.00	6.19E-02	1.54E-06		PER 1.00 DAY	
3.00	2.49E-02	1.13E-06	6.12E-02	1.24E-06	340
5.00	5.93E-03		2.44E-02	9.04E-07	0
7.00	1.83E-03	6.21E-07	5.70E-03	4.88E-07	
10.00		3.46E-07	1.73E-03	2.68E-07	
	4. 10E-04	1.47E-07	3.78E-04	1.12E-07	
15.00	5.13E-05	3.81E-08	4.55E-05	2.79E-08	
20.00	8.39E-06	1.06E-08	7.17E-06	7.49E-09	
25.00	1.65E-06	3.11E-09	1.36E-06	2.12E-09	
30.00	3.71E-07	9.63E-10	2.95E-07	6.35E-10	
35.00	9.17E-08	3.12E-10	7.03E-08	1.99E-10	
40.00	2.45E-08	1.05E-10	1.81E-08	6.46E-11	
45.00	6.97E-09	3.65E-11	4.98E-09		
50. 00	2.10E-09	1.30E-11	1.45E-09	2.17E-11	
60.00	2.18E-10	1.76E-12	1.40E-10	7.48E-12	
70.00	2.62E-11	2.50E-13		9.39E-13	
80.00	3.47E-12	3.78E-14	1.57E-11	1.25E-13	
90.00	4.87E-13		1.94E-12	1.76E-14	
100.00	7.22E-14	6.11E-15	2.54E-13	2.66E-15	
100100	/ • Z Z E - 1 4	1.06E-15	3.51E-14	4.28E-16	

TABLE A2.118

ABSORBED DOSE ABSORBED DOSE ABSORBED DOSE ABSORBED DOSE R,T = 0.0 G/CM2 R,T = 15.0 G/CM2 R,T = 0.0 G/CM2 R,T = 15.0 G/CM2 SHIELD WITHOUT WITHOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUATION R,S (G/CM2) RAD	PROTONS AS		IELD MATERIAL ALUMIN	IUM		
SHIELD WITHOUT WITHOUT WITH DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUATION R.S (G/CM2) RAD RAD RAD RAD RAD RAD S.00 9.17E 01 3.12E-01 2.02E 02 2.98E-01 5.00 2.91E 01 2.23E-01 2.75E 01 1.75E-01 7.00 1.25E 01 1.63E-01 1.15E 01 1.26E-01 10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 5.88E-03 1.35E-03 2.88E-04 7.05E-04 5.52E-05			ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUATION ATTENUATION R.S (G/CM2) RAD RAD RAD RAD 2.00 2.06E 02 3.71E-01 2.02E 02 2.98E-01 3.00 9.17E 01 3.12E-01 8.86E 01 2.49E-01 5.00 2.91E 01 2.23E-01 2.75E 01 1.75E-01 7.00 1.25E 01 1.63E-01 1.15E 01 1.26E-01 10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 7		$R_T = 0.0 \text{ G/CM} 2$	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
R.S (G/CM2) RAD RAD RAD RAD RAD RAD 2.00 2.06E 02 3.71E-01 2.02E 02 2.98E-01 3.00 9.17E 01 3.12E-01 8.86E 01 2.49E-01 5.00 2.91E 01 2.23E-01 2.75E 01 1.75E-01 7.00 1.25E 01 1.63E-01 1.15E 01 1.26E-01 10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05	SHIELD	WITHOUT	WITHOUT	WITH	WITH	
2.00 2.06E 02 3.71E-01 2.02E 02 2.98E-01 3.00 9.17E 01 3.12E-01 8.86E 01 2.49E-01 5.00 2.91E 01 2.23E-01 2.75E 01 1.75E-01 7.00 1.25E 01 1.63E-01 1.15E 01 1.26E-01 10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 5.52E-05	DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNTTA	
2.00 2.06E 02 3.71E-01 2.02E 02 2.98E-01 3.00 9.17E 01 3.12E-01 8.86E 01 2.49E-01 5.00 2.91E 01 2.23E-01 2.75E 01 1.75E-01 7.00 1.25E 01 1.63E-01 1.15E 01 1.26E-01 10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 5.52E-05 <td>R.S (G/CM</td> <td>2) RAD</td> <td>RAD</td> <td>RAD</td> <td>RAD</td> <td></td>	R.S (G/CM	2) RAD	RAD	RAD	RAD	
5.00 2.91E 01 2.23E-01 2.75E 01 1.75E-01 7.00 1.25E 01 1.63E-01 1.15E 01 1.26E-01 10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05	_		3.71E-01	2.02E 02	2.98E-01	
5.00 2.91E 01 2.23E-01 2.75E 01 1.75E-01 7.00 1.25E 01 1.63E-01 1.15E 01 1.26E-01 10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 5.52E-05 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05	3.00	9.17E 01	3.12E-01	8.86E 01	2.49E-01	
7.00 1.25E 01 1.63E-01 1.15E 01 1.26E-01 10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			2.23E-01	2.75E 01	1.75E-01	
10.00 4.61E 00 1.05E-01 4.12E 00 7.83E-02 15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			1.63E-01	1.15E 01	1.26E-01	
15.00 1.29E 00 5.29E-02 1.10E 00 3.79E-02 20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			1.05E-01	4.12E 00	7.83E-02	ω
20.00 4.73E-01 2.84E-02 3.85E-01 1.95E-02 25.00 2.02E-01 1.60E-02 1.57E-01 1.05E-02 30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			5.29E-02	1.10E 00	3.79E-02	341
25.00 2.02E=01 1.60E=02 1.57E=01 1.05E=02 30.00 9.58E=02 9.32E=03 7.11E=02 5.86E=03 35.00 4.90E=02 5.60E=03 3.48E=02 3.37E=03 40.00 2.65E=02 3.46E=03 1.80E=02 2.00E=03 45.00 1.50E=02 2.19E=03 9.74E=03 1.21E=03 50.00 8.78E=03 1.41E=03 5.47E=03 7.46E=04 60.00 3.28E=03 6.15E=04 1.88E=03 2.98E=04 70.00 1.35E=03 2.84E=04 7.05E=04 1.26E=04 80.00 5.88E=04 1.37E=04 2.82E=04 5.52E=05			2.84E-02	3.85E-01	1.95E-02	
30.00 9.58E-02 9.32E-03 7.11E-02 5.86E-03 35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			1.60E-02	1.57E-01	1.05E-02	
35.00 4.90E-02 5.60E-03 3.48E-02 3.37E-03 40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			9.32E-03	7.11E-02	5.86E-03	
40.00 2.65E-02 3.46E-03 1.80E-02 2.00E-03 45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			5.60E-03	3.48E-02	3.37E-03	
45.00 1.50E-02 2.19E-03 9.74E-03 1.21E-03 50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			3.46E-03	1.80E-02	2.00E-03	
50.00 8.78E-03 1.41E-03 5.47E-03 7.46E-04 60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			2.19E-03	9.74E-03	1.21E-03	
60.00 3.28E-03 6.15E-04 1.88E-03 2.98E-04 70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05				5.47E-03	7.46E-04	
70.00 1.35E-03 2.84E-04 7.05E-04 1.26E-04 80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05				1.88E-03	2.98E-04	
80.00 5.88E-04 1.37E-04 2.82E-04 5.52E-05			2.84E-04	7.05E-04	1.26E-04	
				2.82E-04	5.52E-05	
90.00 2.73E=04 6.81E=05 1.20E=04 2.51E=05	90.00		6.81E-05	1.20E-04	2.51E-05	
100.00 1.32E-04 3.51E-05 5.27E-05 1.18E-05				5.27E-05	1.18E-05	

PROTONS AS INCIDENT	PARTICLES SHIELD	MATERIAL	ALUMINUM
RIGIDITY OF PLARE =	50. (MV)		

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}^2$
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUN STTA
R,S (G/CM2)	REM	REM	REM	DTM
2.00	3.84E 02	4.82E-01	3.77E 02	REM
3.00	1.60E 02	4.04E-01	1.54E 02	3.87E-01
5.00	4.69E 01	2.88E-01	4.43E 01	3.22E-01 2.25E-01
7.00	1.92E 01	2.09E-01	1.77E 01	1.60E-01
10.00	6.79E 00	1.33E-01	6.07E 00	9.92E-02
15.00	1.82E 00	6.63E-02	1.55E 00	4.75E-02
20.00	6.46E=01	3.53E-02	5.25E-01	2.42E-02
25.00	2.71E-01	1.97E-02	2. 10E-01	1.29E-02
30.00	1.26E-01	1.14E-02	9.38E-02	7.17E-03
35.00	6.38E-02	6.83E-03	4.53E-02	4. 10E-03
40.00	3.41E-02	4.20E-03	2.32E-02	
45.00	1.91E-02	2.65E-03	1.24E-02	2.41E-03
50.00	1. 12E-02	1.70E-03	6.93E-03	1.46E-03
60.00	4.12E-03	7.35E-04	2.35E-03	8.95E-04
70.00	1.67E-03	3.37E-04	8.75E-04	3.55E-04
80.00	7.26E-04	1.62E-04	3.48E-04	1.49E-04
90.00	3.34E-04	8.02E-05	1.46E-04	6.52E-05
100.00	1.60E-04	4.12E-05	6.42E-05	2.95E-05 1.38E-05

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TABLE A2.120

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF PLARE = 50. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	RAD	RAD	RAD	RAD
2.00	1.00E 02	3.27E-01	9.64E 01	2.61E-01
3.00	4.19E 01	2.60E-01	3.97E 01	2.05E-01
5.00	1.22E 01	1.68E-01	1.12E 01	1.30E-01
7.00	4.85E 00	1.12E-01	4.34E 00	8.44E-02
10.00	1.64E 00	6.35E-02	1.41E 00	4.63E-02
15.00	4.09E-01	2.71E-02	3.31E-01	1.87E-02
20.00	1.35E-01	1.26E-(2	1.03E-01	8.22E-03
25.00	5.26E-02	6.25E-03	3.79E-02	3.84E-03
30.00	2.29E-02	3.26E-03	1.56E-02	1. 90E-03
35.00	1.08E-02	1.77E-03	6.96E-03	9.76E-04
40.00	5.41E-03	9.95E-04	3.29E-03	5. 18E-04
45.00	2.85E-03	5.75E-04	1.64E-03	2.83E-04
50.00	1.56E-03	3.42E-04	8.50E-04	1.59E-04
60.00	5.13E-04	1.27E-04	2.50E-04	5. 24E-05
70.00	1.86E-04	5.07E-05	8.03E-05	1.85E-05
80.00	7.21E-05	2.13E-05	2.76E-05	6.84E-06
90.00	2.98E-05	9.33E-06	1.01E-05	2.63E-06
100.00	1.28E-05	4.23E-06	3.81E-06	1.04E-06

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TABLE A2.121

PROTONS AS INC		IELD MATERIAL POLYET	HYLENE	
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	REM
2.00	1.63E 02	4.24E-01	1.57E 02	3.39E-01
3.00	6.44E 01	3.35E-01	6.10E 01	2.64E-01
5.00	1.75% 01	2.15E-01	1.61E 01	1.66E-01
7.00	6.73E 00	1.42E-01	6.01E 00	1.07E-01
10.00	2.20E 00	7.99E-02	1.89E 00	5.81E-02
15.00	5.29E-01	3.37E-02	4.27E-01	2.31E-02
20.00	1.71E-01	1.55E-02	1.30E-01	1.01E-02
25.00	6.55E-02	7.62E-03	4.70E-02	4.68E-03
30.00	2.82E-02	3.95E-03	1.91E-02	2.30E-03
35.00	1.32E-02	2.14E-03	8.46E-03	1, 17E-03
40.00	6.55E-03	1.19E-03	3.97E-03	6.18E-04
45.00	3.43E-03	6.86E-04	1.97E-03	3. 37E-04
50.00	1.87E-03	4.06E-04	1.01E-03	1.88E-04
60.00	6.08E-04	1.50E-04	2.95E-04	6.18E-05
70.00	2.19E-04	5.95E-05	9.43E-05	2. 17E-05
80.00	8.43E-05	2.49E-05	3.22E-05	7.99E-06
90.00	3.47E-05	1.09E-05	1. 17E-05	3.06E-06
100.00	1.49E-05	4.91E-06	4.42E-06	1.21E-06

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 50. (MV) ABSORBED DOSE ABSORBED DOSE

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	A TTB NUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	3.10E 02	3.90E-01	3.06E 02	3.15E-01
3.00	1.41E 02	3.35E-01	1.38E 02	2.69E-01
5.00	4.63E 01	2.51E-01	4.45E 01	1.98E-01
7.00	2.04E 01	1.90E-01	1.92E 01	1.48E-01
10.00	7.82E 00	1.28E-01	7.20E 00	9.81E-02
15.00	2.30E 00	6.98E-02	2.04E 00	5.15E-02
20.00	8.77E-01	3.99E-02	7.50E-01	2.85E-02
25.00	3.89E-01	2.37E-02	3.21E-01	1.63E-02
30.00	1.90E-01	1.45E-02	1.52E-01	9.68E-03
35.00	1.00E-01	9.16E-03	7.72E-02	5.89E-03
40.00	5.59E-02	5.89E-03	4.15E-02	3.66E-03
45.00	3.26E-02	3.87E-03	2.34E-02	2.32E-03
50.00	1.96E-02	2.59E-03	1.36E-02	1.50E-03
60.00	7.76E-03	1.21E-03	5.01E-03	6.55E-04
70.00	3.33E-03	5.92E-04	2.01E-03	2.99E-04
80.00	1.54E-03	3.03E-04	8.63E-04	1.43E-04
90.00	7.43E-04	1.60E-04	3.89E-04	7.02E-05
100.00	3.75E-04	8.66E-05	1.84E-04	3.55E-05

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 50. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	TUOHTIW	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
2.00	6.37E 02	5.07E-01	6.30E 02	4. 10E-01	
3.00	2.69E 02	4.35E-01	2.64E 02	3.49E-01	
5.00	8.13E 01	3.24E-01	7.81E 01	2.56E-01	
7.00	3.40E 01	2.44E-01	3.21E 01	1.90E-01	
10.00	1.24E 01	1.63E-01	1.14E 01	1.25E-01	ω
15.00	3.47E 00	8.80E-02	3.08E 00	6.48E-02	346
20.00	1.28E 00	4.99E-02	1.09E 00	3.55E-02	
25.00	5.53E-01	2.94E-02	4.57E-01	2.02E-02	
30.00	2.66E-01	1.79E-02	2.12E-01	1.19E-02	
35.00	1. 39E-01	1.12E-02	1.06E-01	7.21E-03	
40.00	7.61E-02	7.20E-03	5.65E-02	4.46E-03	
45.00	4.40E-02	4.70E-03	3.15E-02	2.81E-03	
50.00	2.62E-02	3.13E-03	1.81E-02	1.82E-03	
60.00	1.02E-02	1.46E-03	6.60E-03	7.86E-04	
70.00	4.34E-03	7.08E-04	2.61E-03	3,57E-04	
80.00	1.98E-03	3.60E-04	1.11E-03	1.70E-04	
90.00	9.53E-04	1.89E-04	4.99E-04	8.31E-05	
100.00	4.77E-04	1.02E-04	2.33E-04	4. 18E-05	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 75. (MV)

ABSORBED	D DOSE ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
$R_{\bullet}T = 0.0$	$R_T = 15.0 \text{ G/CM}^2$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD WITHOUTHOUTHOUTHOUTHOUTHOUTHOUTHOUTHOUTHOU	TUOHTIW TUO	WITH	WITH	
DEPTH ATTENUA	TION ATTENUATION	ATTENUATION	MCITAUMBTTA	
R.S (G/CM2) RAD	RAD	RAD	RAD	
2.00 2.18E	02 2.60E 00	2.14E 02	2. 10E 00	
3.00 1.22E	02 2.31E 00	1.18E 02	1.85E 00	
5.00 5.44E		5.13E 01	1.44E 00	
7.00 3.00E		2.77E 01		
10.00 1.49E		1.34E 01	1.14E 00	
15.00 6.18E		5.28E 00	8.20E-01	347
20.00 3.09E			4.92E-01	7
25.00 1.72E		2.52E 00	3.08E-01	
30.00 1.03E		1.34E 00	1.99E-01	
35.00 6.50E-	-1022 01	7.68E-01	1.32E-01	
40.00 4.28E-		4.64E-01	8.96E-02	
45.00 2.90E-		2.92F-01	6.18E-02	
50.00 2.02E-		1.89E-01	4.34E-02	
60.00 1.03E-		1.26E-01	3.08E-02	
		5.92E-02	1.61E-02	
		2.96E-02	8.71E-03	
		1.55E-02	4.85E-03	
		8.41E-03	2.76E-03	
100.00 1.17E-	02 4.79E-03	4.68E-03	1.61E-03	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLAPE = 75. (MV)

$R_T = 0.0 \text{ G/CM2}$ $R_T = 15.0 \text{ G/CM2}$ $R_T = 0.0 \text{ G/CM2}$ $R_T = 15.0 \text{ G/CM2}$	
SHIELD WITHOUT WITHOUT WITH WITH	
DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUA	NCIT
R,S (G/CM2) REM REM REM REM	
2.00 3.74E 02 3.22E 00 3.66E 02 2.60E	0.0
3.00 1.97E 02 2.85E 00 1.90E 02 2.28E	
5.00 8.14E 01 2.26E 00 7.69E 01 1.77E	
7.00 4.31E 01 1.81E 00 3.98E 01 1.39E	
10.00 2.07E 01 1.32E 00 1.85E 01 9.95E-	
15.00 8.22E 00 8.22E-01 7.01E 00 5.91E-0	
20.00 4.00E 00 5.34E-01 3.26E 00 3.67E-0	
25.00 2.19E 00 3.58E-01 1.70E 00 2.36E-0	
30.00 1.30E 00 2.47E-01 9.64E-01 1.56E-0	
35.00 8.08E-01 1.74E-01 5.75E-01 1.05E-0	
40.00 5.28E-01 1.25E-01 3.59E-01 7.21E-0	
45.00 3.54E-01 9.13E-02 2.31E-01 5.05E-0	
50.00 2.45E-01 6.76E-02 1.53E-01 3.57E-0	
60.00 1.24E-01 3.82E-02 7.11E-02 1.85E-0	
70.00 6.75E-02 2.26E-02 3.53E-02 1.00E-0	
80.00 3.82E-02 1.37E-02 1.84E-02 5.54E-0	
90.00 2.26E-02 8.53E-03 9.92E-03 3.15E-0	
100.00 1.37E-02 5.45E-03 5.50E-03 1.83E-0	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 75. (MV) ABSORBED DOSE ABSORBED DOSE

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.29E 02	2.38E 00	1.25E 02	1. 91E 00	
3.00	7.00E 01	2.03E 00	6.63E 01	1.61E 00	
5.00	2.93E 01	1.51E 00	2.69E 01	1.17E 00	
7.00	1.54E 01	1.14E 00	1.38E 01	8.65E-01	
10.00	7.26E 00	7.75E-01	6.26E 00	5.67E-01	
15.00	2.78E 00	4.34E-01	2.26E 00		349
20.00	1.30E 00	2.57E-01	9.93E-01	3.00E-01	9
25.00	6.80E-01	1.59E-01	4.92E-01	1.68E-01	
30.00	3.86E-01	1.02E-01	2.64E-01	9.86E-02	
35.00	2.31E-01	6.78E-02		5.99E-02	
40.00	1.45E-01	4.58E-02	1.50E-01	3.75E-02	
45.00	9.35E-02	3.16E-02	8.83E-02	2.39E-02	
50.00	6.22E-02	2.22E-02	5.41E-02	1.56E-02	
60.00	2.92E-02	1.14E-02	3.39E-02	1.03E-02	
70.00	1.47E-02		1.43E-02	4.69E-03	
80.00	7.76E-03	6.13E-03	6.36E-03	2.23E-03	
90.00	4.27E-03	3.41E-03	2.97E-03	1.09E-03	
100.00	2.42E-03	1.95E-03	1.44E-03	5.49E-04	
100.00	2.426-03	1.15E-03	7.17E-04	2.82E-04	

TABLE A2.127

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 75. (MV)				
RIGIDIII OF TI	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	THELLOUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM} 2$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	REM	REM
2.00	1.96E 02	2.95E 00	1.89E 02	2.37E 00
3.00	1.00E 02	2.51E 00	9.52E 01	1.99E 00
5.00	3.97E 01	1.85E 00	3.65E 01	1.43E 00
7.00	2.02E 01	1.39E 00	1.81E 01	1.05E 00
10.00	9.24E 00	9.35E-01	7.95E 00	6.82E-01
15.00	3.43E 00	5.18E-01	2.78E 00	3.57E-01
20.00	1.57E 00	3.04E-01	1.20E 00	1.98E-01
25.00	8.12E-01	1.87E-01	5.86E-01	1.16E-01
30.00	4.57E-01	1.20E-01	3.11E-01	6.98E-02
35.00	2.72E-01	7.88E-02	1.75E-01	4.35E-02
40.00	1.69E-01	5.30E-02	1.03E-01	2.76E-02
45.00	1.08E-01	3.64E-02	6.25E-02	1.80E-02
50.00	7.18E-02	2.55E-02	3.91E-02	1.19E-02
60.00	3.35E-02	1.30E-02	1.63E-02	5.36E-03
70.00	1.68E-02	6.97E-03	7.23E-03	2.54E-03
80.00	8.80E-03	3.87E-03	3.37E-03	1.24E-03
90.00	4.83E-03	2.21E-03	1.63E-03	6.21E-04
100.00	2.73E-03	1.29E-03	8.07E-04	3.17E-04

PROTONS AS INCIDENT	PARTICLES SHIELI	MATERIAL COPPER
RIGIDITY OF FLARE =	75. (MV)	www.ca.co.co.co.co.co.co.co.co.co.co.co.co.co.

MIGIDITI OF F	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	$R_T = 0.0 \text{ G/CM}^2$	$R_T = 15.0 \text{ G/CM}_2$	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION
R,S (G/CM2)	RAD	RAD	RAD	212
2.00	2.94E 02	2.69E 00	2.90E 02	RAD
3.00	1.67E 02	2.42E 00	1.63E 02	2.18E 00
5.00	7.59E 01	1.99E 00	7.29E 01	1.95E 00
7.00	4.26E 01	1.64E 00	4.02E 01	1.58E 00
10.00	2.17E 01	1.25E 00	2.00E 01	1.29E 00
15.00	9.27E 00	8.27E-01	8.23E 00	9.62E-01
20.00	4.75E 00	5.64E-01		6. 13E-01
25.00	2.71E 00	3.96E-01	4.07E 00	4.04E-01
30.00	1.66E 00	2.83E-01	2.24E 00	2.74E-01
35.00	1.07E 00	2.07E-01	1.32E 00	1.89E-01
40.00	7.16E-01	1.54E-01	8.24E-01	1.34E-01
45.00	4.95E-01	1.15E-01	5.33E-01	9.58E-02
50.00	3.51E-01	8.77E-02	3.56E-01	6.95E-02
60.00	1.86E-01	The same state of the same sta	2.43E-01	5.11E-02
70.00	1. 05E-01	5.24E-02	1.21E-01	2.85E-02
80.00	6.21E-02	3.23E-02	6.34E-02	1.64E-02
90.00	3.79E-02	2.05E-02	3.50E-02	9.72E-03
100.00	2.39E-02	1.33E-02	1.99E-02	5.88E-03
100100	2.335-02	8.80E-03	1.17E-02	3.62E-03

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 75. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION
R, S (G/CM2)	REM	REM	REM	REM
2.00	5.52E 02	3.34E 00	5.46E 02	2.70E 00
3.00	2.93E 02	3.01E 00	2.87E 02	2.42E 00
5.00	1.23E 02	2.45E 00	1. 18E 02	1.94E 00
7.00	6.59E 01	2.02E 00	6.22E 01	1.58E 00
10.00	3.21E 01	1.53E 00	2.96E 01	1.17E 00
15.00	1.31E 01	1.00E 00	1.16E 01	
20.00	6.51E 00	6.77E-01	5.58E 00	7.39E-01
25.00	3.64E 00	4.72E-01	3.01E 00	4.84E-01
30.00	2.19E 00	3.36E-01	1.75E 00	3.26E-01
35.00	1.40E 00	2.44E-01	1.08E 00	2.24E-01
40.00	9.26E-01	1.81E-01		1.57E-01
45.00	6.34E-01	1.35E-01	6.88E-01	1.12E-01
50.00	4.46E-01	1.02E-01	4.55E-01	8.12E-02
60.00	2.34E-01	6.09E-02	3.09E-01	5.95E-02
70.00	1.31E-01		1.51E-01	3.30E-02
80.00	7.67E-02	3.73E-02	7.87E-02	1.89E-02
90.00		2.36E-02	4.31E-02	1.12E-02
100.00	4.65E-02	1.53E-02	2.44E-02	6.73E-03
100.00	2.91E-02	1.01E-02	1.43E-02	4.13E-03

TABLE A2.130

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 100. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNATTA
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	2.14E 02	6.61E 00	2.10E 02	5.36E 00
3.00	1.35E 02	6.03E 00	1.31E 02	4.84E 00
5.00	7.11E 01	5.06E 00	6.71E 01	3.99E 00
7.00	4.45E 01	4.28E 00	4.11E 01	3.32E 00
10.00	2.58E 01	3.38E 00	2.31E 01	2.55E 00
15.00	1.30E 01	2.36E 00	1.11E 01	1.71E 00
20.00	7.58E 00	1.71E 00	6.19E 00	1.18E 00
25.00	4.82E 00	1.26E 00	3.77E 00	8.36E-01
30.00	3.25E 00	9.54E-01	2.43E 00	6.05E-01
35.00	2.28E 00	7.32E-01	1.63E 00	4.44E-01
40.00	1.65E 00	5.71E-01	1.13E 00	3.32E-01
45.00	1.23E 00	4.51E-01	8.04E-01	2.51E-01
50.00	9.29E-01	3.59E-01	5.83E-01	1.91E-01
60.00	5.58E-01	2.34E-01	3.21E-01	1.14E-01
70.00	3.52E-01	1.57E-01	1.85E-01	6.99E-02
80.00	2.30E-01	1 08E-01	1.11E-01	4.38E-02
90.00	1.55E-01	7.59E-02	6.80E-02	2.80E-02
100.00	1.07E-01	5.40E-02	4.27E-02	1.81E-02

RIGIDITY OF I		DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	R EM	
2.00	3.48E 02	7.98E 00	3.41E 02	6.45E 00	
3.00	2.07E 02	7.26E 00	2.00E 02	5.82E 00	
5.00	1.02E 02	6.05E 00	9.61E 01	4.76E 00	
7.00	6.13E 01	5.10E 00	5.66E 01	3.94E 00	
10.00	3.43E 01	4.01E 00	3.08E 01	3.02E 00	
15.00	1.67E 01	2.78E 00	1.42E 01	2.00E 00	۲
20.00	9.50E 00	1.99E 00	7.75E 00	1.37E 00	+
25.00	5.95E 00	1.46E 00	4.64E 00	9.67E-01	
30.00	3.96E 00	1.10E 00	2.96E 00	6.96E-01	
35.00	2.76E 00	8.41E-01	1.97E 00	5.09E-01	
40.00	1.98E 00	6.54E-01	1.35E 00	3.79E-01	
45.00	1.46E 00	5.15E-01	9.55E-01	2.85E-01	
50.00	1.10E 00	4.09E-01	6.89E-01	2.17E-01	
60.00	6.55E-01	2.65E-01	3.76E-01	1. 29E-01	
70.00	4. 10 E-0 1	1.77E-01	2.15E-01	7.86E-02	
80.00	2.67E-01	1.21E-01	1.28E-01	4.91E-02	
90.00	1.79E-01	8.50E-02	7.83E-02	3.13E-02	
100.00	1.22E-01	6.03E-02	4.89E-02	2.02E-02	

TABLE A2.132

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 100. (MV)

ALGIDITI OF F	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.41E 02	6.18E 00	1.36E 02	4.98E 00	
3.00	8.64E 01	5.47E 00	8.20E 01	4.36E 00	
5.00	4.35E 01	4.35E 00	4.01E 01	3.38E 00	
7.00	2.63E 01	3.51E 00	2.36E 01	2.67E 00	
10.00	1.47E 01	2.60E 00	1.27E 01		
15.00	6.96E 00	1.67E 00	5.67E 00	1.91E 00	355
20.00	3.87E 00	1.12E 00	2.97E 00	1.16E 00	S
25.00	2.35E 00	7.75E-01	1.71E 00	7.33E-01	
30.00	1.52E 00	5.53E-01		4.81E-01	
35.00	1.03E 00	4.03E-01	1.04E 00	3. 25E-01	
40.00	7. 18E-01	3.00E-01	6.68E-01	2. 24E-01	
45.00	5. 16E-01		4.40E-01	1.57E-01	
50.00	3.77E-01	2.26E-01	2.99E-01	1.12E-01	
60:00		1.73E-01	2.07E-01	8.03E-02	
70.00	2. 13E-01	1.04E-01	1.04E-01	4.29E-02	
40.000	1.26E-01	6.50E-02	5.46E-02	2.36E-02	
80.00	7.79E-02	4.17E-02	2.97E-02	1.33E-02	
90.00	4.94E-02	2.74E-02	1.66E-02	7.64E-03	
100.00	3. 22E-02	1.83E-02	9.46E-03	4.47E-03	

PROTONS AS INCIDENT PARTICLES SHIELD HATERIAL POLYETHYLENE RIGIDITY OF FLARE = 100. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	TUOHTIN	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 40.00 45.00 50.00 60.00 70.00 80.00 90.00	REM 2.03E 02 1.19E 02 5.69E 01 3.34E 01 1.81E 01 8.36E 00 4.57E 00 2.75E 00 1.76E 00 1.18E 00 8.20E-01 4.27E-01 2.40E-01 1.41E-01 8.68E-02 5.48E-02 3.56E-02	REM 7.45E 00 6.57E 00 5.18E 00 4.16E 00 3.06E 00 1.94E 00 1.29E 00 8.90E-01 6.32E-01 4.59E-01 3.40E-01 2.56E-01 1.95E-01 1.17E-01 7.26E-02 4.64E-02 3.04E-02 2.03E-02	REM 1.96E 02 1.13E 02 5.24E 01 2.99E 01 1.56E 01 6.79E 00 3.50E 00 1.99E 00 1.20E 00 7.64E-01 5.01E-01 3.39E-01 1.17E-01 6.09E-02 3.31E-02 1.84E-02	REM 5.99E 00 5.22E 00 4.02E 00 3.15E 00 2.24E 00 1.34E 00 8.45E-01 5.50E-01 3.70E-01 1.77E-01 1.26E-01 9.04E-02 4.81E-02 2.64E-02 1.48E-02 8.49E-03

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 100. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNSTIA	ATTENUATION	ATTENUATION
R,S (G/CM2)	RAD	RAD	RAD	RAD
2.00	2.73E 02	6.79E 00	2.69E 02	
3.00	1.74E 02	6.27E 00	1.70E 02	5.52E 00
5.00	9.29E 01	5.38E 00	8.91E 01	5.07E 00
7.00	5.88E 01	4.64E 00	5.55E 01	4.28E 00
10.00	3.47E 01	3.77E 00	3.20E 01	3.65E 00
15.00	1.78E 01	2.74E 00		2.90E 00
20.00	1.06E 01	2.04E 00	1.59E 01	2.04E 00
25.00	6.88E 00		9.10E 00	1.47E 00
30.00	4.71E 00	1.55E 00	5.69E 00	1.08E 00
35.00	3.36E 00	1.20E 00	3.76E 00	8.07E-01
40.00	2.46E 00	9.47E-01	2.59E 00	6.13E-01
45.00		7.53E-01	1.84E 00	4.71E-01
50.00	1.86E 00	6.05E-01	1.34E 00	3.66E-01
	1.42E 00	4.92E-01	9.89E-01	2.88E-01
60.00	8.78E-01	3.32E-01	5.69E-01	1.81E-01
70.00	5.67E-01	2.30E-01	3.43E-01	1.17E-01
80.00	3.80E-01	1.63E-01	2.14E-01	7.74E-02
90.00	2.61E-01	1.17E-01	1.37E-01	5.19E-02
100.00	1.84E-01	8.59E-02	9.03E-02	3.54E-02

PROTONS	λS	INCIDENT	PARTICLES	SHIELD	MAT	PERIAL	COPPER
RIGIDITY	OF	PLARE =	100. (HV)			
		DOSE	EOUIVALENT	DC	DSE	EQUIVA	I.ENT

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CH2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
2.00	4.84E 02	8.20E 00	4.78E 02	6.66E 00	
3.00	2.89E 02	7.56E 00	2.82E 02	6.09E 00	
5.00	1.43E 02	6.45E 00	1.37E 02	5.13E 00	
7.00	8.68E 01	5.54E 00	8.20E 01	4.35E 00	
10.00	4.91E 01	4.48E 00	4.53E 01	3.44E 00	
15.00	2.42E 01	3.23E 00	2.15E 01	2.39E 00	358
20.00	1.40E 01	2.39E 00	1. 20E 01	1.71E 00	α
25.00	8.91E 00	1.81E 00	7.36E 00	1.25E 00	
30.00	6.018 00	1.39E 00	4.80E 00	9.33E-01	
35.00	4.24E 00	1.09E 00	3.26E 00	7.06E-01	
40.00	3.08E 00	8.66E-01	2.29E 00	5. 41E-01	
45.00	2.30E 00	6.94E-01	1.66E 00		
50.00	1.75E 00	5.62E-01	1.22E 00	4.19E-01	
60.00	1.07E 00	3.78E-01		3.28E-01	
70.00	6.85E-01	2.61E-01	6.93E-01	2.05E-01	
80.00	4.56E-01		4.14E-01	1.32E-01	
90.00	3.11E-01	1.84E-01	2.57E-01	8.71E-02	
		1.32E-01	1.64E-01	5.82E-02	
100.00	2. 18E-01	9.63E-02	1.07E-01	3.96E-02	

TABLE A2.136

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 125. (NV)

RIGIDITY OF	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R.T = 0.0 G/CM2	R.T = 15.0 G/CH2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	TUOHTIN	WITH	WITH	
DEPTH	ATTENDATION	ATTENUATION	ATTENUATION	NCITAUNATIA	
R.S (G/CH2)	RAD	RAD	RAD	RAD	
2.00	2.06E 02	1.13E 01	2.02E 02	9.19E 00	
3.00	1.40E 02	1.05E 01	1.35E 02	8.44E 00	
5.00	8.13E 01	9.08E 00	7.68E 01	7.18E 00	
7.00	5.49E 01	7.91E 00	5.08E 01	6.15E 00	
10.00	3.49E 01	6.53E 00	3.13E 01	4.94E 00	w
15.00	1.98E 01	4.87E 00	1.69E 01	3.53E 00	359
20.00	1.27E 01	3.73E 00	1.04E 01	2.59E 00	
25.00	8.74E 00	2.92E 00	6.84E 00	1.93E 00	
30.00	6.33E 00	2.32E 00	4.74E 00	1.47E 00	
35.00	4.74E 00	1.87E 00	3.39E 00	1.14E 00	
40.00	3.64E 00	1.53E 00	2.49E 00	8.89E-01	
45.00	2.85E 00	1.26E 00	1.87E 00	7.01E-01	
50.00	2.27E 00	1.05E 00	1.43E 00	5.58E-01	
60.00	1.50E 00	7.41E-01	8.64E-01	3.61E-01	
70.00	1.03E 00	5.37E-01	5.43E-01	2.395-01	
80.00	7.32E-01	3.96E-01	3.52E-01	1.60E-01	
90.00	5.31E-01	2.98E-01	2.33E-01	1. 10E-01	
100.00	3.92E-01	2.26E-01	1.57E-01	7.58E-02	

PROTONS AS	INCIDENT	PARTICLES SE	HIELD MATERIAL ALUMINUM	l
RIGIDITY OF	FLARE =	125. (MV)		
	DOSE	ECUIVALENT	DOSE BOUTVALENC	

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	REM	REM
2.00	3.22E 02	1.34E 01	3.15E 02	1.08E 01
3.00	2.06E 02	1.24E 01	1.99E 02	9.94E 00
5.00	1.13E 02	1.97E 01	1.07E 02	8.41E 00
7.00	7.35E 01	9.26E 00	6.80E 01	7.17E 00
10.00	4.52E 01	7.60E 00	4.06E 01	5.73E 00
15.00	2.47E 01	5.62E 00	2.12E 01	4.06E 00
20.00	1.55E 01	4.28E 00	1.27E 01	2.96E 00
25.00	1.06E 01	3.33E 00	8.25E 00	2. 20E 00
30.00	7.56E 00	2.64E 00	5.65E 00	1.67E 00
35.00	5.61E 00	2.12E 00	4.01E 00	1. 28E 00
40.00	4.28E 00	1.72E 00	2.93E 00	9.99E-01
45.00	3.34E 00	1.42E 00	2. 18E 00	7.86E-01
50.00	2.65E 00	1.17E 00	1.66E 00	6.24E-01
60.00	1.73E 00	8,27E-01	9.94E-01	4.02E-01
70.00	1.18E 00	5.97E-01	6.21E-01	2.65E-01
80.00	8.34E-01	4.39E-01	4.00E-01	1.77E-01
90.00	6.02E-01	3.29E-01	2.64E-01	1.21E-01
100.00	4.43E-01	2.50E-01	1.77E-01	8.35E-02

PROTONS AS INCIDEN	T	PARTICLES	SHIELD	MATERIAL	POLYETHYLENE
RIGIDITY OF FLARE	=	125. (MY	7)		

RIGIDIII OF	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	1.44E 02	1.07E 01	1.39E 02	8.65E 00
3.00	9.55E 01	9.69E 00	9.07E 01	7.73E 00
5.00	5.38E 01	8.01E 00	4.97E 01	6.25E 00
7.00	3.54E 01	6.72E 00	3.18E 01	5.12E 00
10.00	2.18E 01	5.27E 00	1.89E 01	3.88E 00
15.00	1.18E 01	3.66E 00	9.64E 00	2.54E 00
20.00	7.28E 00	2.64E 00	5.61E 00	1.73E 00
25.00	4.85E 00	1.96E 00	3.53E 00	1.22E 00
30.00	3.40E 00	1.49E 00	2.34E 00	8.74E-01
35.00	2.47E 00	1.15E 00	1.60E 00	6.38E-01
40.00	1.84E 00	9.04E-01	1.13E 00	4.73E-01
45.00	1.40E 00	7.20E-01	8.15E-01	3.55E-01
50.00	1.09E 00	5.79E-01	5.97E-01	2.69E-01
60.00	6.85E-01	3.84E-01	3.34E-01	1.58E-01
70.00	4.48E-01	2.63E-01	1.94E-01	9.50E-02
80.00	3.04E-01	1.83E-01	1.16E-01	5.81E-02
90.00	2. 10 E-0 1	1.3 IE-01	7.03E-02	3.63E-02
100.00	1.49E-01	9.47E-02	4.35E-02	2.29E-02

TABLE A2.139

PROTONS AS	INCIDENT	PARTICLES S	HIELD MA	TERIAL POI	YETHYLENE	
RIGIDITY OF	FLARE =	125. (MV)				
	DOSE	EQUIVALENT	DOSE	EQUIVALEN	T DOSE	1

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM2}$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R, S (G/CM2)	REM	REM	REM	REM
2.00	2.02E 02	1.26E 01	1.95E 02	1.02E 01
3.00	1.28E 02	1.14E 01	1.21E 02	9.08E 00
5.00	6.86E 01	9.38E 00	6.33E 01	7.29E 00
7.00	4.39E 01	7.83E 00	3.94E 01	5.95E 00
10.00	2.63E 01	6.09E 00	2.28E 01	4.47E 00
15.00	1.39E 01	4.19E 00	1.13E 01	2.91E 00
20.00	8.45E 00	3.00E 00	6.49E 00	1.97E 00
25.00	5.56E 00	2.22E 00	4.04E 00	1.37E 00
30.00	3.87E 00	1.68E 00	2.65E 00	9.81E-01
35.00	2.79E 00	1.29E 00	1.81E 00	7.14E-01
40.00	2.07E 00	1.01E 00	1.27E 00	5.28E-01
45.00	1.57E 00	8.02E-01	9.11E-01	3.95E-01
50.00	1.22E 00	6.43E-01	6.65E-01	2.98E-01
60.00	7.60E-01	4.25E-01	3.70E-01	1.74E-01
70.00	4.95E-01	2.90E-01	2.13E-01	1.05E-01
80.00	3.34E-01	2.02E-01	1.27E-01	6.39E-02
90.00	2.31E-01	1.44E-01	7.71E-02	3.98E-02
100.00	1.63E-01	1.04E-01	4.76E-02	2.51E-02

PROTONS AS INCREDITY OF F		IELD MATERIAL COPPER ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATT ENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 40.00 45.00 50.00 60.00 70.00 80.00	RAD 2.54E 02 1.73E 02 1.02E 02 6.95E 01 4.48E 01 2.58E 01 1.68E 01 1.17E 01 8.59E 00 6.51E 00 5.06E 00 4.01E 00 3.23E 00 2.18E 00 1.52E 00 1.10E 00 8.11E-01	RAD 1.16E 01 1.08E 01 9.55E 00 8.46E 00 7.14E 00 5.49E 00 4.32E 00 3.46E 00 2.81E 00 2.81E 00 1.91E 00 1.60E 00 1.35E 00 9.84E-01 7.30E-01 5.52E-01 4.23E-01	RAD 2.50E 02 1.69E 02 9.79E 01 6.57E 01 4.13E 01 2.29E 01 1.44E 01 9.72E 00 6.87E 00 5.03E 00 3.77E 00 2.89E 00 2.25E 00 1.41E 00 9.23E-01 6.21E-01 4.28E-01 3.00E-01	RAD 9.43E 00 8.77E 00 7.62E 00 6.67E 00 5.51E 00 4.09E 00 3.11E 00 2.40E 00 1.89E 00 1.50E 00 1.20E 00 9.71E-01 7.93E-01 5.37E-01 3.72E-01 1.87E-01 1.87E-01	363

PROTONS AS IN RIGIDITY OF F	CIDENT PARTICLES SH	IELD MATERIAL COPPER		
AIGIDITI OF F		DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	$R,T = 15.0 \text{ G/CM}_2$
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	5 T M	
2.00	4.31E 02	1.37E 01	REM 4.25E 02	REM
3.00	2.76E 02	1.28E 01	2.70E 02	1.11E 01
5.00	1.52E 02	1.12E 01	1.46E 02	1.03E 01
7.00	9.91E 01	9.92E 00	9.37E 01	8.95E 00
10.00	6.14E 01	8.32E 00		7.80E 00
15.00	3.40E 01	6.36E 00	5.66E 01	6.41E 00
20.00	2.16E 01	4.97E 00	3.02E 01	4.73E 00
25.00	1.48E 01	3.96E 00	1.85E 01	3.57E 00
30.00	1.07E 01	3.20E 00	1.23E 01	2.75E 00
35.00	8.03E 00	2.62E 00	8.56E 00	2.14E 00
40.00	6.18E 00	2.02E 00 2.17E 00	6.19E 00	1.70E 00
45.00	4.87E 00		4.60E 00	1.36E 00
50.00	3.89E 00	1.81E 00	3.50E 00	1.09E 00
60.00	2.60E 00	1.52E 00	2.71E 00	8.90E-01
70.00	1.80E 00	1.10E 00	1.68E 00	6.01E-01
80.00	1.29E 00	8.15E-01	1.09E 00	4.15E-01
90.00	9.49E-01	6.15E-01	7.30E-01	2.92E-01
100.00	7. 11E-01	4.70E-01	5.00E-01	2.08E-01
	/• 11E-01	3.64E-01	3.49E-01	1.50E-01

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PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 150. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	$R_T = 0.0 G/CM2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00	RAD 1.97E 02	RAD 1.59E 01	RAD 1.93E 02	RAD	
3.00 5.00	1.40E 02 8.73E 01	1.49E 01	1.35E 02	1.30E 01 1.20E 01	
7.00 10.00	6.21E 01	1.32E 01 1.18E 01	8.25E 01 5.75E 01	1.05E 01 9.14E 00	
15.00	4.20E 01 2.57E 01	9.97E 00 7.77E 00	3.77E 01 2.21E 01	7.56E 00 5.63E 00	00
20.00 25.00	1.76E 01 1.28E 01	6.19E 00 5.03E 00	1.44E 01 1.00E 01	4.30E 00 3.34E 00	`
30.00 35.00	9.72E 00 7.59E 00	4.14E 00 3.45E 00	7.28E 00 5.44E 00	2.63E 00 2.10E 00	
40.00 45.00	6.07E 00 4.94E 00	2.91E 00 2.47E 00	4.17E 00 3.24E 00	1.69E 00	
50.00 60.00	4.07E 00 2.87E 00	2.11E 00 1.57E 00	2.56E 00	1.37E 00 1.12E 00	
70.00 80.00	2.09E 00	1.20E 00	1.65E 00 1.10E 00	7.66E-01 5.33E-01	
90.00 100.00	1.56E 00 1.19E 00 9.21E-01	9.29E-01 7.29E-01 5.80E-01	7.49E-01 5.21E-01 3.68E-01	3.75E-01 2.68E-01	
		0.002	3.00E-01	1.94E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 150. (MV)

Algibili or		DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R,T = 0.0 \text{ G/CM}^2$	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	5.74
2.00	2.98E 02	1.86E 01		REM
3.00	2.01E 02	1.74E 01	2.92E 02	1.51E 01
5.00	1. 18E 02	1.53E 01	1.94E 02	1.40E 01
7.00	8.13E 01		1.12E 02	1.21E 01
10.00	5.33E 01	1.36E 01	7.53E 01	1.05E 01
		1.14E 01	4.78E 01	8.65E 00
15.00	3.16E 01	8.85E 00	2.71E 01	6.40E 00
20.00	2. 12E 01	7.01E 00	1.73E 01	4.85E 00
25.00	1.52E 01	5.66E 00	1.19E 01	3.75E 00
30.00	1.14E 01	4.65E 00	8.55E 00	2.94E 00
35.00	8.86E 00	3.86E 00	6.34E 00	2.34E 00
40.00	7.04E 00	3.24E 00	4.82E 00	
45.00	5.69E 00	2.74E 00		1.88E 00
50.00	4.67E 00	2.34E 00	3.73E 00	1.52E 00
60.00	3.26E 00		2.93E 00	1.24E 00
70.00	2.36E 00	1.74E 00	1.87E 00	8.44E-01
		1.32E 00	1.24E 00	5.85E-01
80.00	1.76E 00	1.02E 00	8.42E-01	4.11E-01
90.00	1.33E 00	7.98E-01	5.84E-01	2.93E-01
100.00	1.03E 00	6.33E-01	4.11E-01	2.11E-01

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 150. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	$R_T = 0.0 \text{ G/CM}^2$	$R_T = 15.0 \text{ G/CM}^2$	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	TUOHTIW	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 40.00 45.00 50.00 70.00 80.00	RAD 1.44E 02 1.00E 02 6.10E 01 4.25E 01 2.79E 01 1.65E 01 1.09E 01 7.73E 00 5.72E 00 4.36E 00 3.40E 00 2.70E 00 2.18E 00 1.47E 00 1.03E 00	RAD 1.52E 01 1.40E 01 1.19E 01 1.02E 01 8.30E 00 6.09E 00 4.61E 00 3.58E 00 2.84E 00 2.29E 00 1.86E 00 1.54E 00 1.28E 00 9.04E-01 6.57E-01	RAD 1.39E 02 9.54E 01 5.63E 01 3.82E 01 2.42E 01 1.35E 01 8.44E 00 5.64E 00 3.93E 00 2.83E 00 2.83E 00 1.57E 00 1.19E 00 7.16E-01 4.43E-01	RAD 1.23E 01 1.12E 01 9.28E 00 7.80E 00 6.12E 00 4.24E 00 3.04E 00 2.23E 00 1.67E 00 1.27E 00 9.73E-01 7.56E-01 5.92E-01 3.70E-01 2.36E-01
90.00	7.42E-01 5.45E-01 4.07E-01	4.86E-01 3.65E-01 2.79E-01	2.81E-01 1.81E-01 1.18E-01	1.53E-01 1.00E-01 6.68E-02

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 150. (MV)

	2002 7000 (111)				
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNSTTA	ATTENUATION	ATTENUATION	
R,S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 35.00 40.00 45.00 50.00 60.00 70.00 80.00 100.00	REM 1.96E 02 1.31E 02 7.62E 01 5.17E 01 3.32E 01 1.92E 01 1.25E 01 8.76E 00 6.43E 00 4.87E 00 3.78E 00 3.78E 00 1.62E 00 1.13E 00 8.08E-01 5.93E-01 4.41E-01	REM 1.77E 01 1.62E 01 1.37E 01 1.17E 01 9.47E 00 6.89E 00 5.19E 00 4.01E 00 3.16E 00 2.54E 00 2.06E 00 1.69E 00 1.41E 00 9.91E-01 7.18E-01 5.30E-01 3.97E-01 3.03E-01	REM 1.89E 02 1.25E 02 7.04E 01 4.65E 01 2.88E 01 1.56E 01 9.63E 00 6.37E 00 4.41E 00 3.16E 00 2.32E 00 1.73E 00 1.73E 00 7.86E-01 4.85E-01 1.97E-01 1.97E-01	REM 1.43E 01 1.29E 01 1.07E 01 8.93E 00 6.97E 00 4.78E 00 3.40E 00 2.49E 00 1.85E 00 1.40E 00 1.07E 00 8.33E-01 6.51E-01 4.05E-01 1.67E-01 1.09E-01 7.26E-02	

PROTONS AS I	NCIDENT	PARTICLES	SHIELD	MATERIAL	COPPER
RIGIDITY OF	FLARE =	150. (M	V)		
	A BS	ORBED DOSE	2	RSODEED	Dace

	ABSURBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R.T = 0.0 G/CM2	$E_T = 15.0 \text{ G/CM}^2$	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	210
2.00	2.37E 02	1.62E 01	2.33E 02	RAD
3.00	1.69E 02	1.54E 01	1.65E 02	1.33E 01
5.00	1.07E 02	1.38E 01	1.02E 02	1.25E 01
7.00	7.64E 01	1.24E 01	7.21E 01	1. 10 E 0 1
10.00	5.21E 01	1.08E 01	4.81E 01	9.82E 00
15.00	3.24E 01	8.60E 00		8.31E 00
20.00	2.24E 01	7.01E 00	2.88E 01	6.42E 00
25.00	1.65E 01	5.80E 00	1.92E 01	5.06E 00
30.00	1.26E 01	4.86E 00	1.37E 01	4.05E 00
35.00	9.97E 00	4.12E 00	1.01E 01	3.27E 00
40.00	8.05E 00		7.71E 00	2.68E 00
45.00	6.60E 00	3.52E 00	6.00E 00	2.21E 00
50.00	5.50E 00	3.03E 00	4.76E 00	1.84E 00
60.00	3.93E 00	2.62E 00	3.82E 00	1.54E 00
70.00		2.00E 00	2.55E 00	1.09E 00
80.00	2.91E 00	1.56E 00	1.76E 00	7.94E-01
90.00	2.20E 00	1.23E 00	1.24E 00	5.84E-01
	1.70E 00	9.82E+01	8.98E-01	4.35E-01
100.00	1.34E 00	7.93E-01	6.58E-01	3.27E-01

PROTONS A	s I	INCIDENT	PARTICLES	SHIELD	MATERIAL	COPPER
RIGIDITY						

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	B.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	REM
2.00	3.90E 02	1.90E 01	3.84E 02	1.54E 01
3.00	2.62E 02	1.79E 01	2.56E 02	1. 45E 01
5.00	1.54E 02	1.60E 01	1.48E 02	1. 28E 01
7.00	1.06E 02	1.44E 01	1.00E 02	1. 13E 01
10.00	6.98E 01	1.24E 01	6.45E 01	9.54E 00
15.00	4.18E 01	9.83E 00	3.72E 01	7.32E 00
20.00	2.82E 01	7.97E 00	2.42E 01	5. 74E 00
25.00	2.04E 01	6.57E 00	1.69E 01	4.56E 00
30.00	1.55E 01	5.48E 00	1.24E 01	3.68E 00
35.00	1.21E 01	4.62E 00	9.33E 00	3.00E 00
40.00	9.67E 00	3.94E 00	7.21E 00	
45.00	7.88E 00	3.38E 00	5.67E 00	2.47E 00
50.00	6.52E 00	2.92E 00	4.53E 00	2.04E 00
60.00	4.62E 00	2.22E 00		1.71E 00
70.00	3.39E 00	1.72E 00	2.99E 00	1.218 00
80.00	2.56E 00	1.35E 00	2.05E 00	8.75E-01
90.00	1.97E 00		1.442 00	6.42E-01
100.00		1.08E 00	1.03E 00	4.77E-01
100.00	1.54E 00	8.70E-01	7.55E-01	3.58E-01

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 175. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	$R_T = 0.0 \text{ G/CM} 2$	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	1.88E 02	2.01E 01	1.84E 02	1.64E 01
3.00	1.38E 02	1.90E 01	1.34E 02	1.54E 01
5.00	9.07E 01	1.71E 01	8.57E 01	1.35E 01
7.00	6.70E 01	1.54E 01	6.21E 01	1. 20E 01
10.00	4.73E 01	1.34E 01	4.26E 01	1.01E 01
15.00	3.07E 01	1.07E 01	2.64E 01	7.79E 00
20.00	2.20E 01	8.80E 00	1.80E 01	6.11E 00
25.00	1.66E 01	7.34E 00	1.31E 01	4.88E 00
30.00	1.31E 01	6.20E 00	9.80E 00	3.94E 00
35.00	1.05E 01	5.29E 00	7.56E 00	3.21E 00
40.00	8.66E 00	4.55E 00	5.95E 00	2.65E 00
45.00	7.23E 00	3.95E 00	4.75E 00	2.20E 00
50.00	6.11E 00	3.45E 00	3.84E 00	1.832 00
60.00	4.50E 00	2.68E 00	2.59E 00	1.30E 00
70.00	3.42E 00	2.11E 00	1.80E 00	9.35E-01
80.00	2.65E 00	1.69E 00	1.27E 00	6.82E-01
90.00	2.10E 00	1.37E 00	9.17E-01	5.03E-01
100.00	1.68E 00	1.12E 00	6.70E-01	3.74E-01

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 175. (MV)

2019111 01	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	TUOHTIW	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	REM	REM
2.00	2.78E 02	2.32E 01	2.73E 02	1.892 01
3.00	1.94E 02	2.19E 01	1.88E 02	1.76E 01
5.00	1.21E 02	1.96E 01	1.14E 02	1.55E 01
7.00	8.62E 01	1.76E 01	7.98E 01	1.37E 01
10.00	5.91E 01	1.52E 01	5.31E 01	1.15E 01
15.00	3.72E 01	1.21E 01	3.19E 01	8.76E 00
20.00	2.61E 01	9.87E 00	2.14E 01	6.84E 00
25.00	1.95E 01	8.19E 00	1.53E 01	5.43E 00
30.00	1.52E 01	6.89E 00	1.14E 01	4.37E 00
35.00	1.21E 01	5.86E 00	8.70E 00	3.56E 00
40.00	9.92E 00	5.03E 00	6.80E 00	
45.00	8.25E 00	4.36E 00	5.40E 00	2.92E 00 2.42E 00
50.00	6.94E 00	3.80E 00	4.35E 00	
60.00	5.07E 00	2.93E 00	2.91E 00	2.01E 00
70.00	3.83E 00	2.31E 00		1.42E 00
80.00	2.96E 00	1.84E 00	2.01E 00	1.02E 00
90.00	2.33E 00	1.49E 00	1.42E 00	7.42E-01
100.00	1.86E 00	1.22E 00	1.02E 00 7.41E-01	5.46E-01 4.05E-01

TABLE A2.150

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 175. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNTTTA	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	1.41E 02	1.93E 01	1.37E 02	1.57E 01
3.00	1.03E 02	1.79E 01	9.75E 01	1.43E 01
5.00	6.58E 01	1.56E 01	6.09E 01	1.22E 01
7.00	4.77E 01	1.36E 01	4.30E 01	1.04E 01
10.00	3.30E 01	1.14E 01	2.87E 01	8.40E 30
15.00	2.08E 01	8.67E 00	1.70E 01	6.05E 00
20.00	1.45E 01	6.81E 00	1.12E 01	4.48E 00
25.00	1.07E 01	5.46E 00	7.80E 00	3.40E 00
30.00	8.21E 00	4.46E 00	5.65E 00	2.62E 00
35.00	6.48E 00	3.70E 00	4.21E 00	2.04E 00
40.00	5.22E 00	3.10E 00	3.20E 00	1.61E 00
45.00	4.28E 00	2.62E 00	2.48E 00	1.28E 00
50.00	3.55E 00	2.23E 00	1.94E 00	1.03E 00
60.00	2.52E 00	1.65E 00	1.22E 00	6.74E-01
70.00	1.85E 00	1.25E 00	7.93E-01	4.48E-01
80.00	1.39E 00	9.66E-01	5.24E-01	3.02E-01
90.00	1.07E 00	7.54E-01	3.52E-01	2.06E-01
100.00	8.29E-01	5.97E-01	2.39E-01	1.42E-01

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 175. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	$R_T = 0.0 \text{ G/CM}^2$	R.T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION
R, S (G/CM2)	REM	REM	REM	DPK
2.00	1.89E 02	2.23E 01	1.83E 02	REM
3.00	1.32E 02	2.06E 01		1.80E 01
5.00	8.11E 01	1.78E 01	1.25E 02	1.64E 01
7.00	5.74E 01	1.55E 01	7.49E 01	1.39E 01
10.00	3.88E 01	1.28E 01	5.16E 01	1.18E 01
15.00	2.39E 01		3.36E 01	9.46E 00
20.00	1.64E 01	9.72E 00	1.95E 01	6.76E 00
25.00		7.59E 00	1.26E 01	4.98E 00
30.00	1. 20E 01	6.06E 00	8.72E 00	3.76E 00
	9.15E 00	4.93E 00	6.28E 00	2.88E 00
35.00	7.18E 00	4.07E 00	4.65E 00	2. 25E 00
40.00	5.76E 00	3.40E 00	3.53E 00	1.77E 00
45.00	4.70E 00	2.86E 00	2.72E 00	1.40E 00
50.00	3.89E 00	2.44E 00	2. 12E 00	1. 12E 00
60.00	2.75E 00	1.80E 00	1.33E 00	7.33E-01
70.00	2.01E 00	1.36E 00	8.61E-01	
80.00	1.51E 00	1.04E 00	5.67E-01	4.66E-01
90.00	1.15E 00	8.14E-01		3.27E-01
100.00	8.93E-01	6.42E-01	3.80E-01	2.23E-01
		0.425-01	2.58E-01	1.53E-01

TABLE A2.151

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 175. (MV)

RIGIDITY OF	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 G/CM2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	2.22E 02	2.05E 01	2.19E 02	1.67E 01	
3.00	1.64E 02	1.95E 01	1.60E 02	1.58E 01	
5.00	1.08E 02	1.77E 01	1.04E 02	1.42E 01	
7.00	8.06E 01	1.62E 01	7.62E 01	1.28E 01	
10.00	5.74E 01	1.43E 01	5.31E 01	1.10E 01	w
15.00	3.77E 01	1.17E 01	3.36E 01	8.77E 00	375
20.00	2.72E 01	9.82E 00	2.34E 01	7.09E 00	
25.00	2.08E 01	8.32E 00	1.72E 01	5.80E 00	
30.00	1.65E 01	7.13E 00	1.32E 01	4.80E 00	
35.00	1.34E 01	6.17E 00	1.03E 01	4.01E 00	
40.00	1.11E 01	5.38E 00	8.28E 00	3.38E 00	
45.00	9.33E 00	4.72E 00	6.73E 00	2.86E 00	
50.00	7.95E 00	4.17E 00	5.53E 00	2.44E 00	
60.00	5.93E 00	3.30E 00	3.85E 00	1.80E 00	
70.00	4.56E 00	2.65E 00	2.76E 00	1.35E 00	
80.00	3.59E 00	2.16E 00	2.03E 00	1.02E 00	
90.00	2.87E 00	1.78E 00	1.51E 00	7.86E-01	
100.00	2.33E 00	1.48E 00	1.14E 00	6.08E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 175. (MV)

MIGIDINI OF F	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AU N STT A	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM			
2.00	3.56E 02		REM	REM	
3.00	2.48E 02	2.36E 01	3.52E 02	1.93E 01	
5.00		2.25E 01	2.43E 02	1.82E 01	
7.00	1.54E 02	2.04E 01	1.48E 02	1.63E 01	
	1. 10E 02	1.85E 01	1.04E 02	1.46E 01	
10.00	7.55E 01	1.62E 01	6.98E 01	1.25E 01	
15.00	4.78E 01	1.33E 01	4.26E 01	9.90E 00	3
20.00	3.38E 01	1.10E 01	2.90E 01		•
25.00	2.54E 01	9.32E 00	2.10E 01	7.96E 00	
30.00	1.99E 01	7.96E 00		6.49E 00	
35.00	1.60E 01	6.86E 00	1.59E 01	5.35E 00	
40.00	1.31E 01		1.23E 01	4.45E 00	
45.00	1. 10 E 0 1	5.97E 00	9.80E 00	3.74E 00	
50.00		5.22E 00	7.91E 00	3.16E 00	
	9.31E 00	4.60E 00	6.47E 00	2.69E 00	
60.00	6.89E 00	3.62E 00	4.47E 00	1.98E 00	
70.00	5.26E 00	2.90E 00	3.18E 00	1.48E 00	
80.00	4.11E 00	2.36E 00	2.32E 00		
90.00	3.28E 00	1.94E 00	1.72E 00	1. 12E 00	
100.00	2.65E 00	1.61E 00		8.56E-01	
		110111 00	1.30E 00	6.61E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 200. (MV)

RIGIDITY OF	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	$R_T = 15.0 \text{ G/CM}2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.80E 02	2.38E 01	1.76E 02	1.94E 01	
3.00	1.36E 02	2.26E 01	1.31E 02	1.83E 01	
5.00	9.24E 01	2.05E 01	8.74E 01	1.63E 01	
7.00	7.02E 01	1.87E 01	6.51E 01	1.46E 01	
10.00	5.13E 01	1.65E 01	4.62E 01	1.25E 01	Ĺ
15.00	3.48E 01	1.36E 01	2,99E 01	9.86E 00	
20.00	2.58E 01	1.14E 01	2.12E 01	7.90E 00	
25.00	2.01E 01	9.68E 00	1.58E 01	6.43E 00	
30.00	1.62E 01	8.33E 00	1.21E 01	5.29E 00	
35.00	1.34E 01	7.23E 00	9.59E 00	4.40E 00	
40.00	1.12E 01	6.33E 00	7.70E 00	3.68E 00	
45.00	9.56E 00	5.58E 00	6.28E 00	3.10E 00	
50.00	8.23E 00	4.95E 00	5.17E 00	2.63E 00	
60.00	6.28E 00	3.95E 00	3.60E 00	1.92E 00	
70.00	4.91E 00	3.21E 00	2.58E 00	1.42E 00	
80.00	3.93E 00	2.64E 00	1.88E 00	1.06E 00	
90.00	3.19E 00	2.19E 00	1.39E 00	8.00E-01	
100.00	2.62E 00	1.84E 00	1.04E 00	6.09E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM 200. (MV) RIGIDITY OF FLARE = DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT $R_T = 15.0 \text{ G/CM}^2$ R.T = 0.0 G/CM2 $R_{\bullet}T = 0.0 \text{ G/CM}2$ R.T = 15.0 G/CM2SHIELD WITHOUT WI THOUT WITH WITH DEPTH ATTENUATION ATTENUATION ATTENUATION ATTENUATION R.S (G/CM2) REM REM REM REM 2.00 2.61E 02 2.72E 01 2.56E 02 2.21E 01 3.00 1.87E 02 2.58E 01 1.81E 02 2.08E 01 5.00 1.21E 02 2.33E 01 1.14E 02 1.85E 01 7.00 8.91E 01 2.12E 01 8.26E 01 1.65E 01 10.00 6.33E 01 1.86E 01 5.69E 01 1.41E 01 15.00 4.17E 01 1.52E 01 3.57E 01 1.10E 01 20.00 3.03E 01 1.27E 01 2.48E 01 8.78E 00 25.00 2.33E 01 1.07E 01 1.83E 01 7.11E 00 30.00 1.36E 01 9.19E 00 1.40E 01 5.83E 00 7.96E 00 35.00 1.53E 01 1.09E 01 4.83E 00 40.00 1.27E 01 6.95E 00 8.73E 00 4.03E 00 45.00 1.08E 01 6.11E 00 7.08E 00 3.39E 00 50.00 9.26E 00 5.41E 00 5.81E 00 2.87E 00 60.00 7.01E 00 4.30E 00 4.02E 00 2.08E 00 70.00 5.46E 00 3.48E 00 2.86E 00 1.53E 00 80.00 4.35E 00 2.85E 00 2.08E 00 1.15E 00 90.00 3.52E 00

2.37E 00

1.98E 00

100.00

2.88E 00

1.53E 00

1.14E 00

8.63E-01

6.56E-01

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 200. (MV)

AIGIDIII OF F	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.38E 02	2.29E 01	1.34E 02	1.86E 01	
3.00	1.03E 02	2.14E 01	9.82E 01	1.72E 01	
5.00	6.90E 01	1.89E 01	6.39E 01	1.48E 01	
7.00	5.17E 01	1.68E 01	4.66E 01	1.29E 01	
10.00	3.71E 01	1.43E 01	3.22E 01	1.06E 01	u
15.00	2.45E 01	1.12E 01	2.01E 01	7.82E 00	379
20.00	1.77E 01	9.05E 00	1.37E 01	5.96E 00	
25.00	1.35E 01	7.44E 00	9.87E 00	4.62E 00	
30.00	1.07E 01	6.22E 00	7.36E 00	3.64E 00	
35.00	8.66E 00	5.26E 00	5.63E 00	2.90E 00	
40.00	7.15E 00	4.50E 00	4.38E 00	2.34E 00	
45.00	5.99E 00	3.88E 00	3.46E 00	1.90E 00	
50.00	5.08E 00	3.36E 00	2.77E 00	1.55E 00	
60.00	3.75E 00	2.58E 00	1.81E 00	1.05E 00	
70.00	2.85E 00	2.02E 00	1.22E 00	7.182-01	
80.00	2.22E 00	1.61E 00	8.30E-01	4.99E-01	
90.00	1.75E 00	1.29E 00	5.74E-01	3.50E-01	
100.00	1.40E 00	1.05E 00	4.01E-01	2.47E-01	

TABLE A2.157

PROTONS AS INC RIGIDITY OF FI	CIDENT PARTICLES SHEARE = 200. (MV)	IELD MATERIAL POLYET	HYLENE		
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R \cdot T = 0.0 \text{ G/CM}^2$	$R_T = 15.0 \text{ G/CM}^2$	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
2.00	1.83E 02	2.62E 01	1.76E 02	2.12E 01	
3.00	1.31E 02	2.44E 01	1.25E 02	1.95E 01	
5.00	8.40E 01	2.14E 01	7.77E 01	1.67E 01	
7.00	6.14E 01	1.89E 01	5.53E 01	1.44E 01	
10.00	4.31E 01	1.60E 01	3.74E 01	1.18E 01	w
15.00	2.79E 01	1.25E 01	2.28E 01	8.68E 00	380
20.00	1.9 9E 01	1.00E 01	1.54E 01	6.57E 00	
25.00	1.51E 01	8.19E 00	1.10E 01	5.08E 00	
30.00	1.18E 01	6.82E 00	8.12E 00	3.99E 00	
35.00	9.52E 00	5.75E 00	6.18E 00	3.17E 00	
40.00	7.83E 00	4.90E 00	4.79E 00	2.54E 00	
45.00	6.54E 00	4.21E 00	3.77E 00	2.06E 00	
5 0. 00	5.53E 00	3.65E 00	3.01E 00	1.68E 00	
60.00	4.06E 00	2.79E 00	1.96E 00	1.13E 00	
70.00	3.08E 00	2.18E 00	1.31E 00	7.75E-01	
80.00	2.39E 00	1.73E 00	8.94E-01	5.37E-01	
90.00	1.88E 00	1.39E 00	6.17E-01	3.76E-01	
100.00	1.50E 00	1.13E 00	4.30E-01	2.66E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 200. (MV)

ALGEBIE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATIENUATION	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 35.00 40.00	RAD 2. 10E 02 1.59E 02 1.09E 02 8.31E 01 6.12E 01 4.19E 01 3.13E 01 2.45E 01 1.99E 01 1.66E 01 1.40E 01 1.20E 01	RAD 2.42E 01 2.31E 01 2.12E 01 1.96E 01 1.75E 01 1.47E 01 1.25E 01 1.08E 01 9.44E 00 8.29E 00 7.34E 00 6.54E 00	RAD 2.07E 02 1.55E 02 1.05E 02 7.86E 01 5.65E 01 3.73E 01 2.69E 01 2.04E 01 1.60E 01 1.28E 01 1.05E 01 8.66E 00	RAD 1.98E 01 1.88E 01 1.70E 01 1.55E 01 1.36E 01 1.10E 01 9.06E 00 7.55E 00 6.36E 00 5.40E 00 4.61E 00	381
50.00 60.00 70.00 80.00 90.00	1.04E 01 8.02E 00 6.35E 00 5.14E 00 4.21E 00 3.50E 00	5.85E 00 4.76E 00 3.92E 00 3.27E 00 2.75E 00 2.34E 00	7.25E 00 5.21E 00 3.85E 00 2.90E 00 2.22E 00 1.72E 00	3.97E 00 3.43E 00 2.60E 00 2.00E 00 1.55E 00 1.22E 00 9.61E-01	

PROTONS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 200. (MV) DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT

	Jour Profit manual	DODE EQUIVABLAI	DOSE EQUIVALENT	DOSE EGOTAWEENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM2}$
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	REM
2.00	3.29E 02	2.76E 01	3.25E 02	2.26E 01
3.00	2.35E 02	2.64E 01	2.30E 02	2.14E 01
5.00	1.51E 02	2.42E 01	1.45E 02	1.93E 01
7.00	1.11E 02	2.22E 01	1.05E 02	1.75E 01
10.00	7.92E 01	1.97E 01	7.32E 01	1.53E 01
15.00	5.24E 01	1.65E 01	4.66E 01	1.23E 01
20.00	3.83E 01	1.40E 01	3.29E 01	1.01E 01
25.00	2.96E 01	1.20E 01	2.45E 01	8.38E 00
30.00	2.37E 01	1.05E 01	1.90E 01	7.03E 00
35.00	1.95E 01	9.16E 00	1.51E 01	5. 95E 00
40.00	1.64E 01	8.09E 00	1.22E 01	5.07E 00
45.00	1.40E 01	7.18E 00	1.01E 01	4.35E 00
50.00	1. 21E 01	6.42E 00	8.39E 00	3.75E 00
60.00	9.22E 00	5.19E 00	5.98E 00	2.83E 00
70.00	7.25E 00	4.27E 00	4.39E 00	
80.00	5.83E 00	3.55E 00	3.29E 00	2.17E 00
90.00	4.76E 00	2.98E 00		1.68E 00
100.00	3.94E 00		2.50E 00	1.31E 00
100.00	3.34E 00	2.53E 00	1.93E 00	1.04E 00

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 50. (MV)

RIGIDITI OF	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_T = 0.0 G/CM2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNATTA	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 40.00 45.00 50.00	4.39E 00 9.87E-01 1.16E-01 2.37E-02 3.63E-03 3.24E-04 4.73E-05 9.19E-06 2.17E-06 5.90E-07 1.79E-07 5.91E-08 2.09E-08 3.09E-09	RAD 3.01E-05 2.16E-05 1.14E-05 6.20E-06 2.62E-06 7.00E-07 2.09E-07 6.83E-08 2.39E-08 8.91E-09 3.48E-09 1.42E-09 6.02E-10 1.19E-10	RAD 4.17E 00 9.16E-01 1.03E-01 1.99E-02 2.82E-03 2.22E-04 2.86E-05 4.91E-06 1.02E-06 2.45E-07 6.57E-08 1.91E-08 5.96E-09 6.84E-10	RAD 1.48E-05 1.04E-05 5.20E-06 2.70E-06 1.06E-06 2.50E-07 6.61E-08 1.90E-08 5.90E-09 1.94E-09 6.66E-10 2.41E-10 9.01E-11 1.38E-11	383
70.00 80.00 90.00 100.00	5.40E-10 1.08E-10 2.36E-11 5.67E-12	2.59E-11 6.20E-12 1.58E-12 4.28E-13	9.30E-11 1.44E-11 2.46E-12 4.60E-13	2.36E-12 4.38E-13 8.70E-14 1.83E-14	

	AS AS INCI	IDENT PARTICLES SHIT	ELD MATERIAL ALUMINUM	1		
		DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
		$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM2}$	R,T = 15.0 G/CM2	
	SHIELD	WITHOUT	WITHOUT	WITH	WITH	
	DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S	(G/CM2)	REM	REM	REM	REM	
	2.00	2.55E 01	1.04E-04	2.42E 01	5.05E-05	
	3.00	5.28E 00	7.41E-05	4.90E 00	3.49E-05	
	5.00	5.61E-01	3.83E-05	4.95E-01	1.72E-05	
	7.00	1.07E-01	2.06E-05	8.95E-02	8.80E-06	
	10.00	1.52E-02	8.53E-06	1.18E-02	3.38E-06	
	15.00	1.25E-03	2.21E-06	8.55E-04	7.74E-07	384
	20.00	1.71E-04	6.45E-07	1.04E-04	1.99E-07	+
	25.00	3.19E-05	2.06E-07	1.70E-05	5.59E-08	
	30.00	7.28E-06	7.06E-08	3.43E-06	1.70E-08	
	35.00	1.92E-06	2.59E-08	7.97E-07	5.49E-09	
	40.00	5.69E-07	9.95E-09	2.08E-07	1.86E-09	
	45.00	1.84E-07	3.99E-09	5.93E-08	6.62E-10	
	50.00	6.37E-08	1.67E-09	1.81E-08		
	60.00	9.11E-09	3.24E-10	2.02E-09	2.45E-10	
	70.00	1.55E-09	6.92E-11	2.67E-10	3.67E-11	
	80.00	3.02E-10	1.63E-11	4.05E-11	6.13E-12	
	90.00	6.51E-11	4. 10E- 12	6.78E-12	1. 12E-12	
•	100.00	1.54E-11	1.10E-12		2.20E-13	
			101-12	1. 25E-12	4.55E-14	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 50. (MV)

RIGIDITY OF 1	FLARE = 50. (MV) ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$		
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNSTTA	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 35.00 40.00 45.00 50.00 60.00 70.00	RAD 1.20E 00 2.38E-01 2.34E-02 4.11E-03 5.25E-04 3.67E-05 4.33E-06 6.99E-07 1.39E-07 3.22E-08 8.41E-09 2.39E-09 7.39E-10 8.36E-11 1.14E-11	RAD 2.37E-05 1.52E-05 6.58E-06 3.00E-06 1.00E-06 1.93E-07 4.34E-08 1.11E-08 3.10E-09 9.42E-10 3.05E-10 1.04E-10 3.73E-11 5.40E-12 8.82E-13 1.60E-13	RAD 1.03E 00 1.93E-01 1.71E-02 2.74E-03 3.05E-04 1.71E-05 1.63E-06 2.13E-07 3.42E-08 6.43E-09 1.35E-09 3.13E-10 7.80E-11 5.76E-12 5.12E-13 5.19E-14	RAD 1.12E-05 6.89E-06 2.74E-06 1.15E-06 3.38E-07 5.24E-08 9.55E-09 1.97E-09 4.46E-10 1.10E-10 2.87E-11 7.91E-12 2.29E-12 2.16E-13 2.29E-14	385
90.00 100.00	3.09E-13 5.92E-14	3. 15E-14 6.68E-15	5. 91E-15 7. 35E-16	2.71E-15 3.47E-16 4.74E-17	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 50. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNATT A	ATTENUATION	ATTENUATION
R, S (G/CM2)	REM	REM		
2.00	6.25E 00	8.14E-05	REM	REM
3.00	1.14E 00	5.15E-05	5.33E 00	3.78E-05
5.00	1.01E-01	2.18E-05	9.19E-01	2.30E-05
7.00	1.65E-02	9.79E-06	7.30E-02	8.93E-06
10.00	1.96E-03		1.09E-02	3.66E-06
15.00	1. 27E-04	3.19E-06	1.12E-03	1.05E-06
20.00	1.41E-05	5.91E-07	5.76E-05	1.57E-07
25.00	2. 18 E-06	1.29E-07	5.17E-06	2.78E-08
30.00	4.20E-07	3.22E-08	6.45E-07	5.58E-09
35.00	9.46E-08	8.82E-09	1.00E-07	1.24E-09
40.00		2.63E-09	1.83E-08	2.99E-10
45.00	2.41E-08	8.39E-10	3.76E-09	7.69E-11
50.00	6.72E-09	2.82E-10	8.50E-10	2.08E-11
60.00	2.03E-09	9.95E-11	2.08E-10	5.96E-12
70.00	2. 24E-10	1. 4 1E- 11	1.49E-11	5.49E-13
80.00	2.97E-11	2.26E-12	1.29E-12	5.71E-14
	4.55E-12	4.02E-13	1.28E-13	6.64E-15
90.00	7.75E-13	7.84E-14	1.43E-14	8.38E-16
100.00	1.46E-13	1.64E-14	1.76E-15	1. 13E-16

ABSORBED DOSE

ABSORBED DOSE

ALPHAS AS	INCIDENT	PARTICLES	SHIELD	MATERIAL	COPPER
RIGIDITY	OF FLARE :	= 50.	(MV)		
	Al	BSORBED DO	SE	ABSORBED	DOSE

	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	8.94E 00	3.32E-05	8.66E 00	1.66E-05
3.00	2.11E 00	2.48E-05	2.02E 00	1.22E-05
5.00	2.69E-01	1.42E-05	2.49E-01	6.79E-06
7.00	5.82E-02	8.32E-06	5.22E-02	3.87E-06
10.00	9.59E-03	3.89E-06	8.19E-03	1.73E-06
15.00	9.49E-04	1.20E-06	7.49E-04	4.92E-07
20.00	1.50E-04	4.04E-07	1.10E-04	1.54E-07
25.00	3.15E-05	1.47E-07	2.13E-05	5.17E-08
30.00	7.99E-06	5.67E-08	4.99E-06	1.84E-08
35.00	2.32E-06	2.30E-08	1.34E-06	6.95E-09
40.00	7.48E-07	9.79E-09	3.98E-07	2.73E-09
45.00	2.62E-07	4.31E-09	1.29E-07	1.11E-09
50.00	9.80E-08	1.96E-09	4.46E-08	4.67E-10
60.00	1.60E-08	4.42E-10	6.24E-09	9.04E-11
70.00	3.10E-09	1. 10E-10	1.03E-09	1.91E-11
80.00	6.78E-10	2.92E-11	1.92E-10	4.36E-12
90.00	1.65E-10	8.33E-12	3.99E-11	1.06E-12
100.00	4.31E-11	2.51E-12	8.92E-12	2.73E-13

ALPHAS AS INC RIGIDITY OF F		ELD MATERIAL COPPER			
RIGIDITI OF F	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
2.00	5.62E 01	1.15E-04	5.45E 01	5.68E-05	
3.00	1.22E 01	8.56E-05	1.17E 01	4.15E-05	
5.00	1.41E 00	4.81E-05	1.30E 00	2. 26E-05	
7.00	2.84E-01	2.78E-05	2.54E-01	1. 27E-05	
10.00	4.35E-02	1.28E-05	3.71E-02	5.56E-06	(4)
15.00	3.96E-03	3.83E-06	3.12E-03	1.54E-06	388
20.00	5.92E-04	1.26E-06	4.32E-04	4. 71E-07	~
25.00	1. 19E-04	4.50E-07	8.00E-05	1.55E-07	
30.00	2.90E-05	1.71E-07	1.81E-05	5.42E-08	
35.00	8.17E-06	6.81E-08	4.71E-06	2.01E-08	
40.00	2.57E-06	2.85E-08	1.37E-06	7.77E-09	
45.00	8.78E-07	1. 24E-08	4.32E-07	3. 12E-09	
50.00	3.22E-07	5.568-09	1.47E-07	1. 29E-09	
60.00	5.11E-08	1.23E-09	1.99E-08		
70.00	9.62E-09	2.99E-10	3.20E-09	2.45E-10	
80.00	2.05E-09	7.83E-11	5.83E-10	5.09E-11	
90.00	4.89E-10	2.20E-11	1. 18E-10	1. 14E-11	
100.00	1. 26 E- 10	6.55E-12	2.61E-11	2.75E-12	
		0.335-12	2.015-11	6.96E-13	

ALPHAS AS INCIDENT PARTICLES SHIELD KATERIAL ALUMINUM RIGIDITY OF FLAPE = 75. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	$R_T = 0.0 \text{ G/CM}^2$	R.T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTE NUATION	ATTENUATION	ATTENUATION
B.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	3.00E 01	8.61E-03	2.85E 01	4.27E-03
3.00	1.07E 01	6.86E-03	9.88E 00	3.32E-03
5.00	2.44E 00	4.44E-03	2.15E 00	2.05E-03
7.00	8. 17E-01	2.94E-03	6.85E-01	1.29E-03
10.00	2.26E-01	1.65E~03	1.76E-01	6.71E-04
15.00	4.35E-02	6.72E-04	2.99E-02	2.43E-04
20.00	1.17E-02	2.98E-04	7.10E-03	9.48E-05
25.00	3.86E-03	1.40E-04	2.06E-03	3.92E-05
30.00	1.46E-03	6.89E-05	6.85E-04	1.71E-05
35.00	6.02E-04	3.54E-05	2.50E-04	7.75E-06
40.00	2.69E-04	1.87E-05	9.86E-05	3.63E-06
45.00	1.27E-04	1.03E-05	4.11E-05	1.76E-06
50.00	6.32E-05	5.77E-06	1.80E-05	8.71E-07
60.00	1.74E-05	1.93E-06	3.85E-06	2.27E-07
70.00	5.38E+06	6.97E-07	9.28E-07	6.39E-08
80.00	1.81E-06	2.66E-07	2.43E-07	1.90E-08
90.00	6.57E+07	1.06E-07	6.85E-08	5.90E-09
100.00	2.52E-07	4.42E-08	2.04E-08	1.91E-09

ALPHAS AS	INCIDENT PA	ARTICLES	SHIELD	HATE	RIAL	ALUMINUM
RIGIDITY OF	P PLARE =	75.	(MV)			
	DOSE	EOUIVALE	INT I	DOSE	EOUT V	ALENT

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DFPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCIT AU NATTA
R,S (G/CH2)	REM	REM	REM	REM
2.00	1.55E 02	2.62E-02	1.48E 02	1. 27E-02
3.00	5.06E 01	2.07E-02	4.70E 01	9.82E-03
5.00	1.04E 01	1.32E-02	9.18E 00	5.94E-03
7.00	3.24E 00	8.59E-03	2.72E 00	3.69E-03
10.00	8.33E-01	4.71E-03	6.48E-01	1.88E-03
15.00	1.47E-01	1.87E-03	1.01E-01	6.57E-04
20.00	3.74E-02	8.07E-04	2.27E-02	2.51E-04
25.00	1.18E-02	3.70E-04	6.30E-03	1.01E-04
30.00	4. 29E-03	1.79E-04	2.02E-03	4.34E-05
35.00	1.72E-03	9.05E-05	7.15E-04	1.93E-05
40.00	7.52E-04	4.72E-05	2.76E-04	8.89E-06
45.00	3.47E-04	2.55E-05	1.12E-04	4.25E-06
50.00	1.70E-04	1.42E-05	4.83E-05	2.08E-06
60.00	4.51E-05	4.65E-06	9.99E-06	5.30E-07
70.00	1.36E-05	1.64E-06	2.35E-06	1.47E-07
80.00	4.50E-06	6.18E-07	6.03E-07	4.28E-08
90.00	1.60E-06	2.44E-07	1.67E-07	1.31E-08
100.00	6.03E-07	9.98E-08	4.89E-08	4.20E-09

ALPHAS AS INCIDENT	PARTICLES	SHIELD	MATERIAL	POLYETHYLENE
RIGIDITY OF FLARE	75.	(MV)		

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	$R_*T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	N CIT AUN ETT A	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	1.21E 01	7.30E-03	1.04E 01	3.49E-03
3.00	3.96E 00	5.41E-03	3.23E 00	2.47E-03
5.00	8.03E-01	3.06E-03	5.93E-01	1.29E-03
7.00	2.44E-01	1.80E-03	1.64E-01	6.95E-04
10.00	5.99E-02	8.58E-04	3.51E-02	2.91E-04
15.00	9.82E-03	2.81E-04	4.63E-03	7.71E-05
20.00	2.31E-03	1.03E-04	8.78E-04	2.29E-05
25.00	6.70E-04	4.09E-05	2.07E-04	7.34E-06
30.00	2.25E-04	1.73E-05	5.61E-05	2.53E-06
35.00	8.41E-05	7.79E-06	1.70E-05	9.16E-07
40.00	3.39E-05	3.65E-06	5.53E-06	3.46E-07
45.00	1.46E-05	1.77E-06	1.93E-06	1.36E-07
50.00	6.61E-06	8.88E-07	7.06E-07	5.52E-08
60.00	1.52E-06	2.42E-07	1.07E-07	9.78E-09
70.00	3.99E-07	7.16E-08	1.82E-08	1.89E-09
80.00	1.15E-07	2.28E-08	3.40E-09	3.90E-10
90.00	3.55E-08	7.69E-09	6.87E-10	8.51E-11
100.00	1.17E-08	2.71E-09	1.47E-10	1.93E-11

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ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 75. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R.T = 0.0 G/CM2	$R_{*}T = 15.0 \text{ G/CM}2$	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNSTTA	ATTENUATION	ATTENUATION
R, S (G/CM2)	REM	REM	REM	224
2.00	5.60E 01	2.21E-02	4.79E 01	REM
3.00	1.68E 01	1.62E-02	1.36E 01	1.03E-02
5.00	3.06E 00	8.94E-03	2.22E 00	7.23E-03
7.00	8.68E-01	5.17E-03		3.67E-03
10.00	1.98E-01	2.40E-03	5.72E-01	1.94E-03
15.00	2.98E-02	7.59E-04	1.13E-01	7.93E-04
20.00	6.61E-03	2.69E-04	1.37E-02	2.03E-04
25.00	1.84E-03		2.44E-03	5.83E-05
30.00	5.99E-04	1.05E-04	5.49E-04	1.83E-05
35.00	2. 17E-04	4.34E-05	1.44E-04	6.15E-06
40.00		1.92E-05	4.23E-05	2.19E-06
	8.57E-05	8.84E-06	1.35E- 05	8.14E-07
45.00	3.60E-05	4.22E-06	4.60E-06	3.15E-07
50.00	1.61E-05	2.09E-06	1.65E-06	1.26E-07
60.00	3.59E-06	5.59E-07	2.42E-07	2.19E-08
70.00	9.21E-07	1.62E-07	4.04E-08	4.15E-09
80.00	2.60E-07	5.09E-08	7.39E-09	8.46E-10
90.00	7.90E-08	1.69E-08	1.47E-09	1.82E-10
100.00	2.57E-08	5.90E-09	3.10E-10	4.08E-11

ALPHAS AS INCIDEN	T	PARTICLES SHIELD	MATERIAL.	COPPER
RIGIDITY OF FLARE	=	75. (MV)		COLLEN

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	$R_{\bullet}T = 15.0 \text{ G/CM}2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNTTTA	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 40.00 45.00 50.00 70.00	RAD 4.96E 01 1.82E 01 4.38E 00 1.52E 00 4.43E-01 9.11E-02 2.60E-02 8.99E-03 3.54E-03 1.53E-03 7.11E-04 3.50E-04 1.80E-04 5.32E-05 1.76E-05	RAD 9.19E-03 7.55E-03 5.17E-03 3.59E-03 2.15E-03 9.68E-04 4.65E-04 2.35E-04 1.23E-04 6.72E-05 3.77E-05 2.17E-05 1.28E-05 4.70E-06 1.83E-06	RAD 4.80E 01 1.74E 01 4.04E 00 1.36E 00 3.78E-01 7.19E-02 1.90E-02 6.07E-03 2.21E-03 8.84E-04 3.79E-04 1.72E-04 8.20E-05 2.07E-05 5.83E-06	RAD 4.65E-03 3.76E-03 2.49E-03 1.68E-03 9.62E-04 4.01E-04 1.78E-04 8.32E-05 4.05E-05 2.05E-05 1.06E-05 5.64E-06 3.08E-06 9.67E-07 3.23E-07	393
80.00 90.00 100.00	6.33E-06 2.44E-06 9.87E-07	7.55E-07 3.25E-07 1.45E-07	1.79E-06 5.90E-07 2.04E-07	1. 14E-07 4. 19E-08 1. 60E-08	

ALPHAS AS INCI RIGIDITY OF FI	DENT PARTICLES SHI	ELD MATERIAL COPPER			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATIA	ATTENUATION	ATTENUATION	
R.S (G/CH2)	REM	REM	REM	REM	
2.00	2.78E 02	2.81E-02	2.70E 02	1.39E-02	
3.00	9.37E 01	2.29E-02	8.94E 01	1.12E-02	
5.00	2.02E 01	1.54E-02	1.87E 01	7.29E-03	
7.00	6.57E 00	1.06E-02	5.88E 00	4.84E-03	
10.00	1.77E 00	6.21E-03	1.51E 00	2.72E-03	
15.00	3.34E-01	2.73E-03	2.64E-01	1. 10E-03	394
20.00	8.99E-02	1.28E-03	6.56E-02	4. 79E-04	+
25.00	2.97E-02	6.32E-04	2.00E-02	2. 19E-04	
30.00	1.13E-02	3.26E-04	7.04E-03	1.04E-04	
35.00	4.75E-03	1.75E-04	2.74E-03	5.19E-05	
40.00	2.14E-03	9.69E-05	1.14E-03	2.65E-05	
45.00	1.03E-03	5.50E-05	5.09E-04	1.39E=05	
50.00	5.22E-04	3.19E-05	2.37E-04	7.49E-06	
60.00	1. 49 E-04	1.15E-05	5.80E-05	2.31E-06	
70.00	4.79E-05	4.42E-06	1.59E-05		
80.00	1.68E-05	1.79E-06	4.78E-06	7.56E-07	
90.00	6.37E-06	7.60E-07	1.54E-06	2.62E-07	
100.00	2.53E-06	3.35E-07	5.25E-07	9.53E-08 3.59E-08	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 100. (MV)

RIGIDITY OF	FLARE = 100. (MV) ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	$R_T = 0.0 G/CM2$	R.T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}^2$	$R_T = 15.0 \text{ G/CM}^2$
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	7.50E 01	1.40E-01	7.13E 01	6.99E-02
3.00	3.35E 01	1.18E-01	3.11E 01	5.73E-02
5.00	1.07E 01	8.45E-02	9.43E 00	3.92E-02
7.00	4.60E 00	6.18E-02	3.86E 00	2.73E-02
10.00	1.71E 00	3.96E-02	1.33E 00	1.63E-02
15.00	4.84E-01	2.01E-02	3.32E-01	7.29E-03
20.00	1.78E-01	1.08E-02	1.08E-01	3.46E-03
25.00	7.63E-02	6.09E-03	4.07E-02	1.72E-03
30.00	3.62E-02	3.56E-03	1.70E-02	8.89E-04
35.00	1.86E-02	2.14E-03	7.70E-03	4.74E-04
40.00	1.00E-02	1.33E-03	3.67E-03	2.59E-04
45.00	5.70E-03	8.42E-04	1.84E-03	1.45E-04
50.00	3.34E-03	5.43E-04	9.52E-04	8.25E-05
60.00	1.26E-03	2.38E-04	2.79E-04	2.82E-05
70.00	5.17E-04	1.10E-04	8.90E-05	1.01E-05
80.00	2.28E-04	5.30E-05	3.05E-05	3.81E-06
90.00	1.06E-04	2.66E-05	1.10E-05	1.49E-06
100.00	5. 10E-05	1.38E-05	4.13E-06	5.98E-07

ALPHAS AS	S IN	CIDENT	PA	RTICLES	SHIELD	MATERIAL	ALUMINUM
RIGIDITY	OF	FLARE	=	100.	(MV)		

RIGIDITY OF	PLARE = 100. (MV) DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	REM
2.00	3.57E 02	3.90E-01	3.40E 02	1.90E-01
3.00	1.46E 02	3.25E-01	1.36E 02	1.54E-01
5.00	4.18E 01	2.29E-01	3.69E 01	1.04E-01
7.00	1.67E 01	1.65E-01	1.40E 01	7.11E-02
10.00	5.77E 00	1.04E-01	4.49E 00	4.14E-02
15.00	1.50E 00	5.11E-02	1.03E 00	1.81E-02
20.00	5.19E-01	2.68E-02	3.14E-01	8.34E-03
25.00	2.13E-01	1.48E-02	1.14E-01	4.08E-03
30.00	9.74E-02	8.48E-03	4.59E-02	2.06E-03
35.00	4.86E-02	5.02E-03	2.02E-02	1.08E-03
40.00	2.56E-02	3.08E-03	9.37E-03	5.83E-04
45.00	1.42E-02	1.92E-03	4.60E-03	3.21E-04
50.00	8.20E-03	1.22E-03	2.34E-03	1.80E-04
60.00	3.00E-03	5.25E-04	6.65E-04	6.05E-05
70.00	1.20E-03	2.39E-04	2.07E-04	2.14E-05
80.00	5.17E-04	1.13E-04	6.94E-05	7.88E-06
90.00	2.36E-04	5.61E-05	2.46E-05	3.05E-06
100.00	1.12E-04	2.86E-05	9.08E-06	1.21E-06

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ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 100. (MV)

RIGIDITY OF F	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	$R_T = 0.0 \text{ G/CM}_2$	$R_{\bullet}T = 15.0 \text{ G/CM}2$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 45.00 40.00 45.00 50.00 60.00 70.00 80.00	RAD 3.68E 01 1.55E 01 4.52E 00 1.81E 00 6.16E-01 1.55E-01 5.12E-02 2.00E-02 8.74E-03 4.13E-03 2.08E-03 1.10E-03 6.00E-04 1.99E-04 7.19E-05 2.81E-05 1.16E-05 5.01E-06	RAD 1.23E-01 9.80E-02 6.37E-02 4.24E-02 2.42E-02 1.03E-02 4.82E-03 2.39E-03 1.25E-03 6.81E-04 3.84E-04 2.23E-04 4.94E-05 1.98E-05 8.32E-06 3.65E-06 1.67E-06	RAD 3.19E 01 1.27E 01 3.35E 00 1.22E 00 3.64E-01 7.34E-02 1.96E-02 6.21E-03 2.20E-03 8.41E-04 3.43E-04 1.46E-04 6.49E-05 1.40E-05 3.31E-06 8.43E-07 2.26E-07 6.33E-08	RAD 5.93E-02 4.52E-02 2.69E-02 1.65E-02 8.27E-03 2.86E-03 1.08E-03 4.34E-04 1.83E-04 8.06E-05 3.68E-05 1.72E-05 8.24E-06 2.01E-06 5.24E-07 1.43E-07 4.07E-08 1.20E-08	397

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE PIGIDITY OF FLARE = 100. (MV)					
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	R,T = 0.0 G/CM2	$R_T = 15.0 \text{ G/CM}^2$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	REM	REM	REM	REM	
2.00	1.57E 02	3.41E-01	1.34E 02	1.60E-01	
3.00	6.04E 01	2.68E-01	4.88E 01	1.20E-01	
5.00	1.58E 01	1.70E-01	1.15E 01	7.01E-02	
7.00	5.87E 00	1.11E-01	3.88E 00	4.20E-02	
10.00	1.86E 00	6.19E-02	1.07E 00	2.06E-02	
15.00	4.29E-01	2.55E-02	1.97E-01	6.86E-03	
20.00	1.34E-01	1.16E-02	4.98E-02	2.51E-03	
25.00	5.04E-02	5.61E-03	1.51E-02	9.88E-04	
30.00	2. 12E-02	2.88E-03	5.16E-03	4.09E-04	
35. 00	9.80E-03	1.54E-03	1.91E-03	1.76E-04	
40.00	4.80E-03	8.53E-04	7.64E-04	7.93E-05	
45.00	2.49E-03	4.88E-04	3.19E-04	3.66E-05	
50.00	1.34E-03	2.86E-04	1.39E-04	1.73E-05	
60.00	4.31E-04	1.05E-04	2.92E-05	4. 14E-06	
70.00	1.52E-04	4.13E-05	6.74E-06	1.06E-06	
80.00	5.86E-05	1.71E-05	1.69E-06	2.84E-07	
90.00	2.38E-05	7.40E-06	4.45E-07	8.01E-08	
100.00	1.01E-05	3.35E-06	1.23E-07	2.34E-08	

ALPHAS AS INC	IDENT PARTICLES SHI	ELD MATERIAL COPPER			
RIGIDITY OF F	LARE = 100. (MV)				
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATIO N	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.12E 02	1.47E-01	1.08E 02	7.48E-02	
3.00	5.11E 01	1.27E-01	4.87E 01	6.34E-02	
5.00	1.69E 01	9.47E-02	1.56E 01	4.61E-02	
7.00	7.48E 00	7.20E-02	6.70E 00	3.39E-02	
10.00	2.88E 00	4.86E-02	2.46E 00	2. 19E-02	w
15.00	8.57E-01	2.65E-02	6.76E-01	1.11E-02	399
20.00	3.28E-01	1.52E-02	2.39E-01	5.85E-03	
25.00	1.46E-01	9.02E-03	9.84E-02	3. 23E-03	
30.00	7.17E-02	5.55E-03	4.47E-02	1.83E-03	
35.00	3.78E-02	3.49E-03	2.18E-02	1.07E-03	
40.00	2.12E-02	2.25E-03	1.13E-02	6.39E-04	
45.00	1.23E-02	1.49E-03	6.06E-03	3.89E-04	
50.00	7.44E-03	9.95E-04	3.39E-03	2. 4 1E-0 4	
60.00	2.95E-03	4.65E-04	1.15E-03	9.64E-05	
70.00	1.28E-03	2.29E-04	4.23E-04	4.07E-05	
80.00	5.87E=04	1 178-04	1 678-04	4.075-05	

1.17E-04

6.19E-05

3.36E-05

1.67E-04

6.90E-05

2.99E-05

1.78E-05

8.02E-06

3.73E-06

5.87E-04

2.85E-04

1.45E-04

80.00

90.00

100.00

ALPHAS AS INCORIGIDITY OF FI	LARE = 100. (MV)	ELD MATERIAL COPPER			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 40.00 45.00 50.00 60.00 70.00 80.00 90.00	REM 5.77E 02 2.42E 02 7.17E 01 2.95E 01 1.05E 01 2.87E 00 1.04E 00 4.41E-01 2.09E-01 1.07E-01 5.83E-02 3.32E-02 1.96E-02 7.55E-03 3.18E-03 1.43E-03 6.81E-04 3.40E-04	REM 4.11E-01 3.51E-01 2.58E-01 1.94E-01 1.29E-01 6.82E-02 3.82E-02 2.22E-02 1.35E-02 8.34E-03 5.29E-03 3.45E-03 2.29E-03 1.05E-03 5.06E-04 2.55E-04 1.33E-04 7.13E-05	REM 5.59E 02 2.31E 02 6.63E 01 2.65E 01 9.01E 00 2.27E 00 7.57E-01 2.97E-01 1.30E-01 6.16E-02 3.11E-02 1.63E-02 8.94E-03 2.93E-03 1.06E-03 4.07E-04 1.65E-04 7.05E-05	REM 2.04E-01 1.71E-01 1.23E-01 8.92E-02 5.64E-02 2.77E-02 1.43E-02 7.74E-03 4.33E-03 2.48E-03 1.46E-03 8.80E-04 5.38E-04 2.11E-04 8.73E-05 3.76E-05 7.68E-06	400

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 125. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	NCITAUNATIA
R, S (G/CM2)	RAD	RAD	RAD	RAD
2.00	1.26E 02	7.28E-01	1.20E 02	3.65E-01
3.00	6.49E 01	6.32E-01	6.02E 01	3.10E-01
5.00	2.53E 01	4.83E-01	2.23E 01	2.26E-01
7.00	1.26E 01	3.75E-01	1.06E 01	1.66E-01
10.00	5.62E 00	2.61E-01	4.38E 00	1.08E-01
15.00	2.01E 00	1.51E-01	1.38E 00	5.50E-02
20.00	8.88E-01	9.11E-02	5.37E-01	2.94E-02
25.00	4.46E-01	5.74E-02	2.38E-01	1.63E-02
30.00	2.43E-01	3.71E-02	1.15E-01	9.33E-03
35.00	1.42E-01	2.47E-02	5.88E-02	5.48E-03
40.00	8.61E-02	1.68E-02	3.15E-02	3.29E-03
45.00	5.44E-02	1.16E-02	1.76E-02	2.00E-03
50.00	3.53E-02	8.13E-03	1.01E-02	1.24E-03
60.00	1.61E-02	4.19E-03	3.56E-03	4.98E-04
70.00	7.83E-03	2.24E-03	1.35E-03	2.08E-04
80.00	4.04E-03	1.25E-03	5.42E-04	9.01E-05
90.00	2.17E-03	7.17E-04	2.26E-04	4.02E-05
100.00	1.21E-03	4.21E-04	9.82E-05	1.84E-05

ALPHAS AS INCIDENT P RIGIDITY OF FLARE =	ARTICLES SHIELD	MATERIAL ALUMINUM
DOSE	EQUIVALENT	DOSP POUTERS

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
SHIELD	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
	TUOHTIN	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 40.00 45.00 50.00 60.00 70.00 80.00	REM 5.64E 02 2.65E 02 9.23E 01 4.29E 01 1.77E 01 5.79E 00 2.42E 00 1.16E 00 6.12E-01 3.47E-01 2.05E-01 1.27E-01 8.12E-02 3.59E-02 1.70E-02 8.62E-03 4.55E-03	REM 1.89E 00 1.63E 00 1.22E 00 9.37E-01 6.39E-01 3.59E-01 2.11E-01 1.30E-01 8.28E-02 5.42E-02 3.63E-02 2.48E-02 1.72E-02 8.67E-03 4.57E-03 2.50E-03 1.42E-03	REM 5.37E 02 2.46E 02 8.14E 01 3.60E 01 1.38E 01 3.97E 00 1.46E 00 6.20E-01 2.88E-01 1.44E-01 7.52E-02 4.12E-02 2.31E-02 7.95E-03 1.16E-03 4.75E-04	REM 9.26E-01 7.77E-01 5.57E-01 4.05E-01 2.56E-01 1.27E-01 6.62E-02 3.61E-02 2.02E-02 1.17E-02 6.91E-03 4.16E-03 2.55E-03 1.00E-03 4.10E-04 1.75E-04
	2.50E+03	8.24E-04	2.03E-04	7.73E-05 3.49E-05

402

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 125. (MV)

ABSORBE	D DOSE ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
R,T = 0.	0 G/CM2 R.T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD WITH	TUOHT WITHOUT	WITH	WITH	
DEPTH ATTENU	NCITAUNATTA NOITA	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00 3.00 3.42E 5.00 1.24E 7.00 5.87E 10.00 2.43E 15.00 7.89E 20.00 3.22E 25.00 1.50E 30.00 7.67E 35.00 4.18E 40.00 2.40E 45.00 1.43E 50.00 8.81E 60.00 7.67E 70.00 1.59E 70.00 1.59E	01	RAD 6.07E 01 2.82E 01 9.26E 00 3.99E 00 1.45E 00 3.77E-01 1.24E-01 4.70E-02 1.94E-02 8.58E-03 3.99E-03 1.92E-03 9.59E-04 2.56E-04 7.38E-05 2.25E-05	RAD 3. 18E-01 2. 53E-01 1. 63E-01 1. 63E-01 6. 02E-02 2. 45E-02 1. 07E-02 4. 92E-03 2. 35E-03 1. 16E-03 5. 92E-04 3. 08E-04 1. 63E-04 4. 82E-05 1. 50E-05 4. 83E-06	403
100.00 1.87E-	10455 04	7.16E-06 2.37E-06	1.62E-06 5.56E-07	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 125. (MV)

RIGIDITY OF	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	NCITAUNTTTA	ATTENUATION	ATTENUATION
R.S (G/CM2)	REM	REM	REM	DPM
2.00	2.79E 02	1.70E 00	2.39E 02	REM 7.98E-01
3.00	1.25E 02	1.39E 00	1.01E 02	
5.00	4.04E 01	9.60E-01	2.96E 01	6.28E-01
7.00	1.78E 01	6.77E-01	1.18E 01	3.97E-01 2.57E-01
10.00	6.85E 00	4.19E-01	3.95E 00	1. 40E-01
15.00	2.04E 00	2.03E-01	9.45E-01	5.49E-02
20.00	7.89E-01	1.07E-01	2.93E-01	
25.00	3.54E-01	5.92E-02	1.06E~01	2.32E-02
30.00	1.75E-01	3.44E-02	4.26E-02	1.05E-02
35.00	9.29E-02	2.07E-02	1.83E-02	4.90E-03
40.00	5.21E-02	1.28E-02	8.32E-03	2.38E-03
45.00	3.05E-02	8. 16E-03	3.93E-03	1.20E-03
50.00	1.84E-02	5.29E-03	1.93E-03	6.14E-04
60.00	7.36E-03	2.35E-03	5.01E-04	3.21E-04
70.00	3.17E-03	1.10E-03		9.32E-05
80.00	1. 47E-03	5.42E-04	1.41E-04	2.85E-05
90.00	7.08E-04	2.77E-04	4.24E-05	9.05E-06
100.00	3.55E-04		1.33E-05	3.00E-06
	3. 335-04	1.46E-04	4.34E-06	1.02E-06

ALPHAS AS	I	NCIDENT		PARTICLES	SHIELD	MATERIAL	COPPER
RIGIDITY	OF	FLARE	=	125.	(M V)		

RIGIDITY OF	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R.T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	N CIT AU N TTT A	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.77E 02	7.58E-01	1.71E 02	3.88E-01	
3.00	9.23E 01	6.71E-01	8.81E 01	3.38E-01	
5.00	3.70E 01	5.30E-01	3.42E 01	2.59E-01	
7.00	1.89E 01	4.24E-01	1.69E 01	2.01E-01	
10.00	8.65E 00	3.08E-01	7.39E 00	1.40E-01	4
15.00	3.21E 00	1.89E-01	2.53E 00	7.91E-02	405
20.00	1.46E 00	1.20E-01	1.07E 00	4.66E-02	
25.00	7.57E-01	7.88E-02	5.11E-01	2.83E-02	
30.00	4.25E-01	5.32E-02	2.65E-01	1.77E-02	
35.00	2.53E-01	3.66E-02	1.46E-01	1.13E-02	
40.00	1.58E-01	2.57E-02	8.41E-02	7.31E-03	
45.00	1.02E-01	1.83E-02	5.02E-02	4.83E-03	
50.00	6.78E-02	1.33E-02	3.08E-02	3.23E-03	
60.00	3.20E-02	7.18E-03	1.25E-02	1.50E-03	
70.00	1.63E-02	4.06E-03	5.41E-03	7.24E-04	
80.00	8.70E-03	2.36E-03	2.47E-03	3.60E-04	
90.00	4.87E-03	1.41E-03	1.18E-03	1.84E-04	
100.00	2.81E-03	8.66E-04	5.82E-04	9.65E-05	

ALPHAS AS INCIRIGIDITY OF FI	DENT PARTICLES SHI	ELD MATERIAL COPPER			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION	
R, S (G/CM2)	REM	REM	REM	REM	
2.00	8.56E 02	1.98E 00	8.30E 02	9.85E-01	
3.00	4. 10E 02	1.74E 00	3.91E 02	8.51E-01	
5.00	1.47E 02	1.35E 00	1.36E 02	6.44E-01	
7.00	6.98E 01	1.07E 00	6.25E 01	4.93E-01	
10.00	2.95E 01	7.63E-01	2.52E 01	3.36E-01	4
15.00	1.00E 01	4.54E-01	7.93E 00	1.85E-01	406
20.00	4.32E 00	2.83E-01	3.15E 00	1.07E-01	0.
25.00	2. 13E 00	1.82E-01	1.44E 00	6.35E-02	
30.00	1.15E 00	1.21E-01	7.20E-01	3.90E-02	
35.00	6.68E-01	8.18E-02	3.85E-01	2.44E-02	
40.00	4.06E-01	5.65E-02	2.17E-01	1.56E-02	
45.00	2.57E-01	4.00E-02	1.26E-01	1.02E-02	
50.00	1.67E-01	2.86E-02	7.62E-02	6.76E-03	
60.00	7.66E-02	1.51E-02	2.98E-02	3.06E-03	
70.00	3.80E-02	8.43E-03	1.26E-02	1.46E-03	
80.00	1.98E-02	4.83E-03	5.63E-03	7. 15E-04	
90.00	1.09E-02	2.85E-03	2.64E-03	3.60E-04	
100.00	6.20E-03	1.73E-03	1.28E-03	1.87E-04	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 150. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	$R_{\bullet}T = 15.0 \text{ G/CM}2$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.76E 02	2.15E 00	1.67E 02	1.08E 00	
3.00	9.91E 01	1.91E 00	9.19E 01	9.40E-01	
5.00	4.42E 01	1.52E 00	3.89E 01	7.13E-01	
7.00	2.44E 01	1.23E 00	2.05E 01	5.47E-01	
10.00	1.22E 01	9.06E-01	9.51E 00	3.75E-01	4
15.00	5.09E 00	5.69E-01	3.49E 00	2.08E-01	407
20.00	2.55E 00	3.72E-01	1.54E 00	1.20E-01	
25.00	1.42E 00	2.52E-01	7.59E-01	7.20E-02	
30.00	8.54E-01	1.75E-01	4.02E-01	4.41E-02	
35.00	5.41E-01	1.24E-01	2.24E-01	2.76E-02	
40.00	3.55E-01	8.95E-02	1.30E-01	1.76E-02	
45.00	2.41E-01	6.56E-02	7.79E-02	1.14E-02	
50.00	1.68E-01	4.87E-02	4.79E-02	7.47E-03	
60.00	8.65E-02	2.79E-02	1.92E-02	3.33E-03	
70.00	4.72E-02	1.65E-02	8.14E-03	1.54E-03	
80.00	2.71E-02	1.01E-02	3.64E-03	7.31E-04	
90.00	1.61E-02	6.34E-03	1.68E-03	3.57E-04	
100.00	9.86E-03	4.05E-03	7.99E-04	1.78E-04	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 150. (MV) DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT DOSE EQUIVALENT

	$R_T = 0.0 \text{ G/CM}^2$	$R_T = 15.0 \text{ G/CM}^2$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	REM
2.00	7.45E 02	5.30E 00	7.09E 02	2.60E 00
3.00	3.83E 02	4.67E 00	3.56E 02	2.23E 00
5.00	1.53E 02	3.65E 00	1.35E 02	1.66E 00
7.00	7.83E 01	2.90E 00	6.57E 01	1.26E 00
10.00	3.63E 01	2.10E 00	2.83E 01	8.45E-01
15.00	1.39E 01	1.28E 00	9.52E 00	4.56E-01
20.00	6.56E 00	8.20E-01	3.97E 00	2.57E-01
25.00	3.51E 00	5.43E-01	1.87E 00	1.51E+01
30.00	2.04E 00	3.71E-01	9.59E-01	
35.00	1.25E 00	2.58E-01	5.20E-01	9.08E-02
40.00	8.04E-01	1.84E-01		5.58E-02
45.00	5.35E-01	1.34E-01	2.95E-01	3.51E-02
50.00	3.67E-01		1.73E-01	2.25E-02
60.00		9.79E-02	1.04E-01	1.46E-02
	1.83E-01	5.49E-02	4.06E-02	6.37E-03
70.00	9.76E-02	3.20E-02	1.68E-02	2.89E-03
80.00	5.50E-02	1.93E-02	7.37E-03	1.35E-03
90.00	3.21E-02	1.20E-02	3.35E-03	6.54E-04
100.00	1.93E-02	7.57E-03	1.57E-03	3.22E-04

TABLE A2.186

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 150. (MV)

RIGIDITY OF	FLARE = 150. (MV) ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.05E 02	1.97E 00	9.17E 01	9.58E-01	
3.00	5.71E 01	1.69E 00	4.71E 01	7.84E-01	
5.00	2.40E 01	1.25E 00	1.80E 01	5.35E-01	
7.00	1.27E 01	9.49E-01	8.64E 00	3.72E-01	
10.00	5.98E 00	6.45E+01	3.57E 00	2.23E-01	4
15.00	2.30E 00	3.61E-01	1.11E 00	1.01E-01	409
20.00	1.08E 00	2.15E-01	4.19E-01	4.86E-02	
25.00	5.67E-01	1.33E-01	1.78E-01	2.44E-02	
30.00	3.21E-01	8.59E-02	8.20E-02	1.27E-02	
35.00	1.93E-01	5.67E-02	3.98E-02	6.79E-03	
40.00	1.21E-01	3.85E-02	2.02E-02	3.72E-03	
45.00	7.84E-02	2.66E-02	1.06E-02	2.08E-03	
50.00	5.21E-02	1.87E-02	5.69E-03	1.18E-03	
60.00	2.46E-02	9.61E-03	1.75E-03	3.95E-04	
70.00	1.24E-02	5.18E-03	5.76E-04	1.38E-04	
80.00	6.57E-03	2.88E-03	1.98E-04	4.98E-05	
90.00	3.61E-03	1.66E-03	7.08E-05	1.85E-05	
100.00	2.05E-03	9.77E-04	2.61E-05	7.06E-06	

ALPHAS AS INC. RIGIDITY OF F	IDENT PARTICLES SHI	ELD MATERIAL POLYETH	YLENE		
algibili of F	LARE = 150. (MV) DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}2$	$R_T = 15.0 \text{ G/CM}^2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNETTA	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	D 71 M	
2.00	3.98E 02	4.83E 00	3.41E 02	REM	
3.00	1.97E 02	4.08E 00		2.28E 00	
5.00	7.39E 01	2.96E 00	1.59E 02	1.84E 00	
7.00	3.63E 01	2.21E 00	5.41E 01	1.23E 00	
10.00	1.59E 01	1.46E 00	2.41E 01	8.39E-01	
15.00	5.65E 00	7.92E-01	9.22E 00	4.90E-01	410
20.00	2.51E 00	4.59E-01	2.62E 00	2. 14E-01	0
25.00	1. 26E 00		9.38E-01	1.00E-01	
30.00	6.94E-01	2.78E-01	3.83E-01	4.92E-02	
35.00	4.07E-01	1.76E-01	1.70E-01	2.52E-02	
40.00	2.49E-01	1.14E-01	8.06E-02	1.32E-02	
45.00		7.63E-02	4.00E-02	7.16E-03	
50.00	1.59E-01	5.22E-02	2.06E-02	3.94E-03	
	1.04E-01	3.62E-02	1.09E-02	2.21E-03	
60.00	4.78E-02	1.82E-02	3.27E-03	7.27E-04	
70.00	2.35E-02	9.68E-03	1.05E-03	2.50E-04	
80.00	1.23E-02	5.32E-03	3.56E-04	8.91E-05	
90.00	6.65E-03	3.02E-03	1.25E-04	3.28E-05	
100.00	3.72E-03	1.76E-03	4.56E-05	1.24E-05	

3.28E-05 1.24E-05

RIGIDITY OF F	LARE = 150. (MV)	ELD MATERIAL COPPER			
	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION	
R,S (G/CM2) 2.00	RAD 2.36E 02	RAD	RAD	RAD	
3.00	1.35E 02	2.23E 00 2.01E 00	2.28E 02 1.28E 02	1.14E 00 1.02E 00	
5.00	6.13E 01	1.65E 00	5.67E 01	8.08E-01	
7.00 10.00	3.45E 01 1.77E 01	1.36E 00 1.04E 00	3.09E 01	6.48E-01	
15.00	7.60E 00	6.87E-01	1.51E 01 6.00E 00	4.74E-01 2.89E-01	411
20.00	3.91E 00	4.70E-01	2.85E 00	1.83E-01	
25.00 30.00	2.23E 00 1.37E 00	3.29E-01	1.51E 00	1.19E-01	
35.00	8.85E-01	2.36E-01 1.73E-01	8.54E-01 5.10E-01	7.89E-02	
40.00	5.94E-01	1.28E-01	3.16E-01	5.34E-02 3.66E-02	
45.00	4.11E-01	9.65E-02	2.02E-01	2.55E-02	
50.00	2.91E-01	7.36E-02	1.32E-01	1.80E-02	

4.39E-02

2.72E-02

1.73E-02

1.12E-02

7.43E-03

1.32E-01

6.03E-02

2.91E-02

1.47E-02

7.69E-03

4.15E-03

1.80E-02

9.19E-03

4.87E-03

2.64E-03

1.47E-03

8.32E-04

1.55E-01

8.76E-02

5.18E-02

3. 18E-02

2.00E-02

60.00

70.00

80.00

90.00

100.00

ALPHAS AS INC. RIGIDITY OF F.	IDENT PARTICLES SHI LARE = 150. (MV)	ELD MATERIAL COPPER			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM}_2$	$R_T = 15.0 \text{ G/CM2}$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	NCITAUNATTA	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 35.00 40.00 45.00 50.00 60.00 70.00 80.00	REM 1.08E 03 5.66E 02 2.30E 02 1.20E 02 5.71E 01 2.25E 01 1.09E 01 5.95E 00 3.52E 00 2.21E 00 1.44E 00 9.81E-01 6.80E-01 1.94E-01 1.12E-01 6.75E-02	REM 5.50E 00 4.93E 00 3.98E 00 3.25E 00 2.44E 00 1.57E 00 1.05E 00 7.21E-01 5.09E-01 3.67E-01 2.68E-01 1.99E-01 1.51E-01 8.81E-02 5.36E-02 3.36E-02 2.15E-02	REM 1.05E 03 5.40E 02 2.13E 02 1.08E 02 4.88E 01 1.77E 01 7.95E 00 4.02E 00 2.20E 00 1.28E 00 7.70E-01 4.83E-01 3.10E-01 1.37E-01 6.43E-02 3.18E-02	REM 2.75E 00 2.42E 00 1.90E 00 1.50E 00 1.08E 00 6.41E-01 3.97E-01 2.52E-01 1.65E-01 1.10E-01 7.44E-02 5.12E-02 3.57E-02 1.79E-02 9.32E-03 4.99E-03	412
					03

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 175. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R, S (G/CH2)	RAD	RAD	RAD	RAD	
2.00	2.20E 02	4.61E 00	2.09E 02	2.33E 00	
3.00	1.32E 02	4.16E 00	1.23E 02	2.05E 00	
5.00	6.49E 01	3.41E 00	5.73E 01	1.61E 00	
7.00	3.86E 01	2.83E 00	3.23E 01	1.27E 00	
10.00	2.10E 01	2.17E 00	1.64E 01	9.04E-01	
15.00	9.78E 00	1.45E 00	6.71E 00	5.34E-01	
20.00	5.35E 00	1.01E 00	3.24E 00	3.27E-01	
25.00	3.22E 00	7.16E-01	1.72E 00	2.05E-01	
30.00	2.07E 00	5.23E-01	9.75E-01	1.32E-01	
35.00	1.39E 00	3.88E-01	5.77E-01	8.68E-02	
40.00	9.68E-01	2.93E-01	3.55E-01	5.78E-02	
45.00	6.91E-01	2.24E-01	2.23E-01	3.90E-02	
50.00	5.06E-01	1.73E-01	1.44E-01	2.67E-02	
60.00	2.84E-01	1.07E-01	6.30E-02	1.28E-02	
70.00	1.69E-01	6.82E-02	2.91E-02	6.36E-03	
80.00	1.04E-01	4.45E-02	1.40E-02	3.23E-03	
90.00	6.68E-02	2.97E-02	6.96E-03	1.68E-03	
100.00	4. 36E-02	2.03E-02	3.54E-03	8.92E-04	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 175. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REA	REM	REM
2.00	8.90E 02	1.09E 01	8.47E 02	5. 34E 00
3.00	4.89E 02	9.71E 00	4.54E 02	4.66E 00
5.00	2. 14E 02	7.84E 00	1.89E 02	
7.00	1.18E 02	6.40E 00	9.91E 01	3.58E 00
10.00	5.97E 01	4.83E 00	4.64E 01	2.78E 00
15.00	2.55E 01	3.13E 00	1.75E 01	1.95E 00
20.00	1. 32E 01	2.12E 00	7.98E 00	1.12E 00
25.00	7.60E 00	1.48E 00		6.69E-01
30.00	4.72E 00	1.06E 00	4.06E 00	4. 12E-01
35.00	3.08E 00	7.77E-01	2.22E 00	2.61E-01
40.00	2. 10E 00	5.77E-01	1.28E 00	1.69E-01
45.00	1.47E 00		7.69E-01	1. 11E-01
50.00	1.06E 00	4.37E-01	4.74E-01	7.38E-02
60.00		3.35E-01	3.01E-01	5.00E-02
70.00	5.76E-01	2.02E-01	1.28E-01	2.35E-02
	3.35E-01	1.27E-01	5.78E-02	1.15E-02
80.00	2.03E-01	8.18E-02	2.72E-02	5.76E-03
90.00	1. 28E-01	5.39E-02	1.33E-02	2.96E-03
100.00	8.23E-02	3.64E-02	6.68E-03	1.55E-03

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 175. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R.T = 0.0 G/CH2	R.T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUA TION	ATTENUATION	ATTENUATION	
R.S (G/CM2)	RAD	RAD	RAD	RAD	
2.00	1.40E 02	4.28E 00	1.22E 02	2.09E 00	
3.00	8. 12E 01	3.73E 00	6.72E 01	1.74E 00	
5.00	3.79E 01	2.88E 00	2.85E 01	1.24E 00	
7.00	2.16E 01	2.26E 00	1.48E 01	8.92E-01	
10.00	1.12E 01	1.62E 00	6.75E 00	5.62E-01	4
15.00	4.89E 00	9.80E-01	2.36E 00	2.75E-01	415
20.00	2.53E 00	6.24E-01	9.88E-01	1.42E-01	
25.00	1.45E 00	4.14E-01	4.57E-01	7.59E-02	
30.00	8.86E-01	2.82E-01	2.27E-01	4.19E-02	
35.00	5.69E-01	1.98E-01	1.18E-01	2.37E-02	
40.00	3.80E-01	1.41E-01	6.37E-02	1.37E-02	
45.00	2.61E-01	1.03E-01	3.54E-02	8.04E-03	
50.00	1.84E-01	7.57E-02	2.01E-02	4. 78E-03	
60.00	9.59E-02	4.26E-02	6.87E-03	1.75E-03	
70.00	5.30E-02	2.50E-02	2.47E-03	6.68E-04	
80.00	3.06E-02	1.51E-02	9.302-04	2.61E-04	
90.00	1.83E-02	9.33E-03	3.60E-04	1.04E-04	
100.00	1. 12E-02	5.91E-03	1.43E-04	4. 27E-05	

ALPHAS AS INCIDENT PARTICLES SHIELD NATERIAL POLYETHYLENE RIGIDITY OF FLARE = 175. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R,S (G/CM2)	REM	REM	REM	D TOM
2.00	5.03E 02	1.00E 01	4.32E 02	REM
3.00	2.67E 02	8.63E 00	2. 17E 02	4.74E 00
5.00	1. 12E 02	6.52E 00	8.17E 01	3.91E 00
7.00	5.93E 01	5.03E 00	3.95E 01	2.71E 00
10.00	2.86E 01	3.51E 00	1.66E 01	1.92E 00
15.00	1.15E 01	2.06E 00		1. 18E 00
20.00	5.61E 00	1.28E 00	5.34R 00	5.59E-01
25.00	3.09E 00	8.29E-01	2.11E 00	2.81E-01
30.00	1.84E 00	5.54E-01	9.38E-01	1.47E-01
35.00	1. 15E 00		4.50E-01	7.97E-02
40.00	7.52E-01	3.83E-01	2.29E-01	4.44E-02
45.00		2.69E-01	1.21E-01	2.52E-02
	5.06E-01	1.93E-01	6.60E-02	1.46E-02
50.00	3.51E-01	1.41E-01	3.70E-02	8.64E-03
60.00	1.79E-01	7.77E-02	1.23E-02	3.10E-03
70.00	9.69E-02	4.50E-02	4.34E-03	1.17E-03
80.00	5.50E-02	2.68E-02	1.61E-03	4.51E-04
90.00	3. 25E-02	1.64E-02	6.15E-04	1.78E-04
100.00	1.97E-02	1.03E-02	2.41E-04	7. 24E-05

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ALPHAS AS	INCIDENT	PARTICLES	SHIELD	MATERIAL	COPPER
RIGIDITY (OF FLARE	= 175.			

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R.T = 0.0 G/CM2	R.T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	A TTENUATION	ATTENUATION	ATTENUATION	
R.S (G/CM2) 2.00 3.00 5.00 7.00 10.00 15.00 20.00 25.00 30.00 40.00 45.00 50.00 60.00 70.00 80.00	RAD 2.85E 02 1.74E 02 8.69E 01 5.24E 01 2.91E 01 1.39E 01 7.78E 00 4.78E 00 3.13E 00 2.14E 00 1.51E 00 1.51E 00 1.10E 00 8.16E-01 4.73E-01 2.88E-01 1.83E-01 1.20E-01	RAD 4.75E 00 4.35E 00 3.66E 00 3.10E 00 2.45E 00 1.71E 00 1.23E 00 9.06E-01 6.78E-01 5.17E-01 4.00E-01 3.13E-01 2.47E-01 1.59E-01 1.05E-01 7.08E-02 4.88E-02	RAD 2.77E 02 1.66E 02 8.03E 01 4.69E 01 2.49E 01 1.10E 01 5.68E 00 3.23E 00 1.95E 00 1.23E 00 8.06E-01 5.41E-01 3.71E-01 1.84E-01 9.57E-02 5.20E-02 2.91E-02	RAD 2.45E 00 2.21E 00 1.80E 00 1.48E 00 1.12E 00 7.24E-01 4.81E-01 3.28E-01 2.27E-01 1.60E-01 1.15E-01 8.30E-02 6.06E-02 3.33E-02 1.88E-02 1.09E-02 6.41E-03	417
100.00	8.06E-02	3.41E-02	1.67E-02	3.838-03	

ALPHAS AS INC	IDENT PARTICLES SHI LARE = 175. (MV)	ELD MATERIAL COPPER			
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R_T = 0.0 \text{ G/CM}^2$	$R_T = 15.0 \text{ G/CM}^2$	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
2.00	1.26E 03	1.12E 01	1.22E 03	5.62E 00	
3.00	6.98E 02	1.02E 01	6.67E 02	5.03E 00	
5.00	3.12E 02	8.45E 00	2.88E 02		
7.00	1.74E 02	7.08E 00	1.56E 02	4.04E 00	
10.00	8.97E 01	5.50E 00	7.66E 01	3.28E 00	
15.00	3.92E 01	3.74E 00	3.10E 01	2.44E 00	418
20.00	2.07E 01	2.63E 00	1.51E 01	1.53E 00	œ
25.00	1.22E 01	1.90E 00	8.21E 00	9.98E-01	
30.00	7.68E 00	1.40E 00		6.68E-01	
35.00	5.10E 00	1.05E 00	4.79E 00	4.55E-01	
40.00	3.52E 00	8.04E-01	2.94E 00	3.16E-01	
45.00	2.50E 00	6.20E-01	1.88E 00	2.24E-01	
50.00	1.83E 00		1.23E 00	1.60E-01	
60.00	1.03E 00	4.84E-01	8.32E-01	1.15E-01	
70.00		3.06E-01	3.99E-01	6.23E-02	
80.00	6.10E-01	1.98E-01	2.03E-01	3.45E-02	
	3.80E-01	1.32E-01	1.08E-01	1.97E-02	
90.00	2.44E-01	9.02E-02	5.92E-02	1.15E-02	
100.00	1.62E-01	6.24E-02	3.35E-02	6.80E-03	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 200. (MV)

	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	R.T = 15.0 G/CM2
SHIELD	WITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R. S (G/CM2)	RAD	RAD	RAD	RAD
2.00	2.58E 02	8.11E 00	2.45E 02	4.12E 00
3.00	1.63E 02	7.40E 00	1.51E 02	3.66E 00
5.00	8.59E 01	6.20E 00	7.57E 01	2.93E 00
7.00	5.38E 01	5.26E 00	4.52E 01	2.36E 00
10.00	3.13E 01	4.16E 00	2.44E 01	1.73E 00
15.00	1.58E 01	2.91E 00	1.09E 01	1.07E 00
20.00	9.27E 00	2.10E 00	5.61E 00	6.85E-01
25.00	5.91E 00	1.56E 00	3.15E 00	4.48E-01
30.00	3.98E 00	1.18E 00	1.88E 00	2.99E-01
35.00	2.80E 00	9.06E-01	1.16E 00	2.03E-01
40.00	2.03E 00	7.07E-01	7.44E-01	1. 40E-01
45.00	1.51E 00	5.58E-01	4.88E-01	9.75E-02
50.00	1.15E 00	4.45E-01	3.26E-01	6.86E-02
60.00	6.90E-01	2.91E-01	1.53E-01	
70.00	4.35E-01	1.95E-01	7.50E-02	3.50E-02
80.00	2.85E+01	1.34E-01		1.83E-02
90.00	1.92E-01	9.41E-02	3.82E-02	9.79E-03
100.00	1. 32E-01		2.00E-02	5.34E-03
	1. J2B-01	6.69E-02	1.07E-02	2.95E-03

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL ALUMINUM RIGIDITY OF FLARE = 200, (MV)

RIGIDITY OF					
	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R_T = 0.0 \text{ G/CM}^2$	R.T = 15.0 G/CM2	$R_{\bullet}T = 0.0 \text{ G/CM}2$	$R_{\bullet}T = 15.0 \text{ G/CM}2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	T			
2.00	1.00E 03	REM	REM	REM	
3.00		1.84E 01	9.54E 02	9.06E 00	
5.00	5.79E 02	1.66E 01	5.37E 02	7.99E 00	
7.00	2.72E 02	1.37E 01	2.40E 02	6.28E 00	
	1.58E 02	1.15E 01	1.33E 02	4.99E 00	
10.00	8.55E 01	8.89E 00	6.65E 01	3.60E 00	_
15.00	3.97E 01	6.05E 00	2.72E 01		420
20.00	2. 19E 01	4.27E 00	1.33E 01	2.16E 00	C
25.00	1.34E 01	3.11E 00	7.15E 00	1.35E 00	
30.00	8.74E 00	2.31E 00	4.12E 00	8.67E-01	
35.00	5.99E 00	1.75E 00		5.69E-01	
40.00	4.24E 00	1.35E 00	2.49E 00	3.80E-01	
45.00	3.10E 00	1.05E 00	1.55E 00	2.59E-01	
50.00	2. 31E 00		1.00E 00	1.78E-01	
60.00	1.35E 00	8.28E-01	6.57E-01	1.24E-01	
70.00	8.33E-01	5.33E-01	3.00E-01	6.21E-02	
80.00		3.51E-01	1.43E-01	3.19E-02	
90.00	5.36E-01	2.39E-01	7.19E-02	1.69E-02	
100.00	3.54E-01	1.66E-01	3.69E-02	9.11E-03	
100.00	2.42E-01	1.16E-01	1.96E-02	4.99E-03	
				T	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 200. (MV)

RIGIDIII OF F	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	$R_T = 0.0 \text{ G/CM2}$	$R_{\bullet}T = 15.0 \text{ G/CM}2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R. S (G/CM2)	RAD	RAD	RAD	R A D	
2.00	1.71E 02	7.58E 00	1.49 02	3.71E 00	
3.00	1.05E 02	6.71E 00	8.69E 01		
5.00	5.29E 01	5.34E 00	3.99E 01	3.15E 00	
7.00	3.21E 01	4.31E 00	2.21E 01	2.30E 00	
10.00	1.79E 01	3.21E 00	1.08E 01	1.70E 00	
15.00	8.54E 00	2.05E 00	4.14E 00	1.12E 00	421
20.00	4.75E 00	1.38E 00	1.87E 00	5.78E-01	_
25.00	2.90E 00	9.58E-01		3. 14E-01	
30.00	1.88E 00	6.85E-01	9.21E-01	1.77E-01	
35.00	1. 27E 00	4.99E-01	4.83E-01	1.02E-01	
40.00	8.89E-01	3.72E-01	2.65E-01	6.01E-02	
45.00	6.38E-01		1.50E-01	3.61E-02	
50.00	4.67E-01	2.80E-01	8.69E-02	2.20E-02	
60.00	2.64E-01	2.14E-01	5.15E-02	1.36E-02	
70.00	1.57E-01	1.29E-01	1.89E-02	5.32E-03	
80.00		8.05E-02	7.33E-03	2.15E-03	
90.00	9.65E-02	5.17E-02	2.93E-03	8.97E-04	
	6.13E-02	3.39E-02	1.21E-03	3.79E-04	
100.00	3.99E-02	2.26E-02	5.09E-04	1.63E-04	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL POLYETHYLENE RIGIDITY OF FLARE = 200. (MV)

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	$R,T = 15.0 \text{ G/CM}^2$	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION	
R,S (G/CM2)	REM	REM	REM	REM	
2.00	5.91E 02	1.71E 01	5.08E 02	8.10E 00	
3.00	3.32E 02	1.49E 01	2.70E 02	6.79E 00	
5.00	1.50E 02	1.16E 01	1.10E 02	4.86E 00	
7.00	8.44E 01	9.23E 00	5.64E 01	3.53E 00	
10.00	4.38E 01	6.71E 00	2.55E 01	2.26E 00	1
15.00	1.93E 01	4.16E 00	9.01E 00	1.13E 00	1
20.00	1.02E 01	2.72E 00	3.84E 00	5.99E-01	
25.00	5.97E 00	1.85E 00	1.82E 00	3.30E-01	
30.00	3.75E 00	1.30E 00	9.26E-01	1.87E-01	
35.00	2.48E 00	9.32E-01	4.94E-01	1.09E-01	
40.00	1.70E GO	6.85E-01	2.74E-01	6.45E-02	
45.00	1.20E 00	5.11E-01	1.56E-01	3.88E-02	
50.00	8.63E-01	3.85E-01	9.13E-02	2.36E-02	
60.00	4.76E-01	2.29E-01	3.28E-02	9.14E-03	
70.00	2.77E-01	1.40E-01	1.25E-02	3.64E-03	
80.00	1.68E-01	8.91E-02	4.91E-03	1.50E-03	
90.00	1.05E-01	5.78E-02	2.00E-03	6.30E-04	
100.00	6.78E-02	3.82E-02	8.35E-04	2.69E-04	

ALPHAS AS INCIDENT PARTICLES SHIELD MATERIAL COPPER RIGIDITY OF FLARE = 200. (MV)

AIGIDIII OF F	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE	ABSORBED DOSE
	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2
SHIELD	HITHOUT	WITHOUT	WITH	WITH
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTENUATION
R.S (G/CM2)	RAD	RAD	RAD	RAD
2.00	3.26E 02	8.33E 00	3.16E 02	4.31E 00
3.00	2.08E 02	7.69E 00	1.99E 02	3.92E 00
5.00	1.12E 02	6.60E 00	1.03E 02	3.26E 00
7.00	7.09E 01	5.70E 00	6.35E 01	2.73E 00
10.00	4.20E 01	4.63E 00	3.59E 01	2.12E 00
15.00	2.17E 01	3.37E 00	1.71E 01	1.43E 00
20.00	1.29E 01	2.51E 00	9.45E 00	9.86E-01
25.00	8.39E 00	1.91E 00	5.66E 00	6.96E-01
30.00	5.76E 00	1.49E 00	3.59E 00	4.99E-01
35.00	4. 11E 00	1.17E 00	2.37E 00	3.63E-01
40.00	3.02E 00	9.31E-01	1.61E 00	2.68E-01
45.00	2.28E 00	7.50E-01	1.12E 00	2.00E-01
50.00	1.75E 00	6.09E-01	7.97E-01	1.50E-01
60.00	1.08E 00	4.11E-01	4.20E-01	8.66E-02
70.00	7.00E-01	2.86E-01	2.32E-01	5.14E-02
80.00	4.68E-01	2.02E-01	1.33E-01	3.11E-02
90.00	3.23E-01	1.46E-01	7.82E-02	1.92E-02
100.00	2. 27E-01	1.07E-01	4.70E-02	1. 20 E-02

ALPHAS AS	INCID	ENT P	ARTICLES	SHIELD	MATERIAL	COPPER
RIGIDITY C	F FLA	RE =	200.	(MV)		

	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	DOSE EQUIVALENT	
	$R_T = 0.0 \text{ G/CM}^2$	R,T = 15.0 G/CM2	R,T = 0.0 G/CM2	R,T = 15.0 G/CM2	
SHIELD	WITHOUT	WITHOUT	WITH	WITH	
DEPTH	ATTENUATION	ATTENUATION	ATTENUATION	ATTEN UATIO N	
R,S (G/CM2)	REM	REM	REM	REM	
2.00	1.38E 03	1.89E 01	1.34E 03	9.51E 00	
3.00	8.05E 02	1.73E 01	7.68E 02	8.58E 00	
5.00	3.85E 02	1.47E 01	3.56E 02	7.03E 00	
7.00	2.27E 02	1.25E 01	2.03E 02	5.82E 00	
10.00	1.24E 02	1.00E 01	1.06E 02	4.44E 00	
15.00	5.88E 01	7.09E 00	4.65E 01	2.92E 00	
20.00	3.31E 01	5.18E 00	2.42E 01	1.97E 00	
25.00	2.05E 01	3.87E 00	1.39E 01	1.36E 00	
30.00	1.36E 01	2.96E 00	8.48E 00	9.64E-01	
35.00	9.43E 00	2.29E 00	5.44E 00	6.92E-01	
40.00	6.77E 00	1.80E 00	3.61E 00	5.03E-01	
45.00	5.00E 00	1.44E 00	2.46E 00	3.71E-01	
50.00	3.77E 00	1.16E 00	1.72E 00	2.76E-01	
60.00	2.26E 00	7.65E-01	8.79E-01	1.56E-01	
70.00	1.43E 00	5.24E-01	4.75E-01	9.15E-02	
80.00	9.36E-01	3.65E-01	2.66E-01	5.45E-02	
90.00	6.35E-01	2.60E-01	1.54E-01	3.32E-02	
100.00	4.40E-01	1.89E-01	9.12E-02	2.06E-02	

Appendix 3

SYSTEMATICS OF CALCULATIONS THAT INCLUDE SECONDARY-PARTICLE PRODUCTION AND TRANSPORT

A3.1 INCIDENT VAN ALLEN BELT AND SOLAR-FLARE PROTONS

equivalent distributions in tissue when Van Allen belt and solar-flare proton spectra are incident on the spacecraft shield are given here. These distributions were obtained using the nucleon-meson transport code NMTC⁶⁹ for the geometry shown in Fig. 3.1. The mechanisms utilized in this code for the production of secondary particles and their subsequent transport through the shield and tissue are described. Included is a discussion of the incident-particle energy and angular-biasing techniques that were employed to improve the statistical accuracy in the secondary-particle dose distributions. The absorbed-dose and dose-equivalent particle distributions computed for the incident Van Allen belt and solar-flare proton spectra for all of the shield materials and shield thicknesses considered in this report are also given.

A3.1.1 The Nucleon-Meson Transport Code NMTC

The nucleon-meson transport code NMTC simulates the transport of nucleons and pions below ~ 3 GeV by means of Monte Carlo techniques. Detailed descriptions of NMTC are available, 69,92,104 but, for completeness, a discussion of the physical interactions included in the calculations is given here.

Charged-Particle Energy Loss. The energy loss of protons, charged pions, and muons is treated in the continuous slowing-down approximation using known energy loss per unit distance of such particles. 69,104

Pion production in the intranuclear-cascade calculation is based on the isobar model of Sternheimer and Lindenbaum. Only single- and double-pion production in nucleon-nucleon collisions and single-pion production in pion-nucleon collisions are accounted for. The evaporation portion of the intranuclear-cascade-evaporation calculations is carried out with the code EVAP-4. This code gives an estimate of the energy of the emitted deuterons, tritons, The's, alpha particles, and photons, as well as an estimate

^{110.} R. M. Sternheimer and S. J. Lindenbaum, "Extension of the Isobaric Nucleon Model for Pion Production in Pion-Nucleon, Nucleon-Nucleon, and Antinucleon-Nucleon Interactions," Phys. Rev. 123, 333 (1961); "Pion Production in Pion-Nucleon Collisions," Phys. Rev. 109, 1723 (1958); "Isobaric Nucleon Model for Pion Production in Nucleon-Nucleon Collisions," Phys. Rev. 105, 1874 (1957).

^{111.} M. P. Guthrie, "EVAP-4: Another Modification of a Code to Calculate Particle Evaporation from Excited Compound Nuclei," Oak Ridge National Laboratory Report ORNL-TM-3119, 1969.

of the kinetic energy of the recoiling nucleus from a nonelastic collision. The differential cross sections for particle production from nucleon and pion nonelastic collisions with hydrogen nuclei are the same as those used in the intranuclear-cascade calculations of Bertini. 87

Proton-nucleus nonelastic collisions below 15 MeV and pion-nucleus non-elastic collisions below 2.2 MeV (except for the capture of π^- -mesons at rest) are neglected. Particle production from neutron-nucleus nonelastic collisions below 15 MeV is obtained using the code EVAP-4¹¹¹ in conjunction with the total nonelastic cross-section data on the OSR¹¹² master cross-section tape.*

Nucleon-Nucleus and Pion-Nucleus Elastic Collisions. The elastic collisions of protons and pions with all nuclei other than hydrogen are neglected. The differential cross sections for the elastic collisions of neutrons with nuclei other than hydrogen are those given on the O5R master cross-section tape. The differential cross sections for the elastic collisions of nucleons with energy > 15 MeV and pions with energy > 2.2 MeV with hydrogen nuclei are taken from experimental data and are the same as those used in the intranuclear-cascade calculations. 84-87,113 The differential cross sections for the elastic collisions of neutrons with energy < 15 MeV with hydrogen nuclei are taken from the O5R master cross-section tape.*

^{*}This cross-section tape, together with references to all of the data used, is available on request from the Radiation Shielding Information Center of the Oak Ridge National Laboratory.

D. C. Irving et al., "OSR, a General-Purpose Monte Carlo Neutron Transport Code," Oak Ridge National Laboratory Report ORNL-3622, 1965.

H. W. Bertini, "Monte Carlo Calculations on Intranuclear Cascades," Oak Ridge National Laboratory Report ORNL-3383, 1963.

Charged-Pion Decay in Flight. Charged pions are unstable and may decay into muons and neutrinos. Charged-pion decay in flight is taken into account using the known pion lifetime. When a decay occurs, the energy and angular distribution of the produced muon is obtained by assuming that the decay is isotropic in the rest frame of the pion and by using the Lorentz transformation to transform the distribution from the pion rest frame into the laboratory system. The produced neutrino is of no interest here since it deposits no energy in the tissue.

Charged-Pion Decay and Capture at Rest. When a positively charged pion comes to rest, it will ultimately decay into a positively charged muon and a neutrino. The energy and angular distribution of the muon may be obtained in the same manner as when a positively charged pion decays in flight. When a negatively charged pion comes to rest, it will not, with a very large probability, decay but will be captured by a nucleus and will produce a variety of secondary particles. For the results reported here, it is assumed that all negatively charged pions that come to rest are captured, and the energy and angular distribution of the particles produced as a result of this capture is obtained from the intranuclear-cascade-evaporation model of nuclear reactions. 114

Neutral-Pion Decay. The neutral pion is very unstable and, from a practical point of view, it may be assumed that this particle decays into two photons at its point of origin. The two photons have equal and opposite momenta in the rest system of the pion, and the sum of their energies in this system is equal to the pion rest energy. The energy-angle distribution of the photons in the laboratory system is obtained by assuming that the decay is isotropic in the rest system of the pion.

^{114.} M. P. Guthrie, R. G. Alsmiller, Jr., and H. W. Bertini, "Calculation of the Capture of Negative Pions in Light Elements and Comparison with Experiments Pertaining to Cancer Radiotherapy," Nucl. Instr. Meth. 66, 29 (1968); with erratum Nucl. Instr. Meth. 91, 669 (1971).

Muon Decay in Flight and at Rest. Muons are unstable and may decay into electrons or positrons, depending on the charge of the muons, and neutrinos. Muon decay in flight is taken into account using the known muon lifetime, and muons that come to rest are assumed to decay immediately.

Thermal-Neutron Capture. Neutrons that become thermalized will be captured by hydrogen and nitrogen in the tissue. The energy deposited by the photons produced by thermal-neutron capture in hydrogen and by the protons produced by thermal-neutron capture in nitrogen is included in the calculations by using the known capture cross section.

A3.1.2 Details of the Transport Calculations

In the calculations given in the test, protons, neutrons, charged pions, and muons are transported through the shield and tissue sphere (see Fig. 3.1), taking into account the energy and angular distributions with which the particles are produced. Heavy nuclei, i.e., nuclei with mass number > 1, are not transported but are assumed to deposit their energy at their point of origin. Since the range of these particles is very short, this assumption is quite valid. Electrons and positrons from muon decay and photons from nonelastic nucleon-nucleus collisions and π^0 decay are also assumed to deposit their energy at their point of origin. This assumption is not entirely valid, but since these particles do not contribute significantly to the dose, it is acceptable.

Energy and Angular Biasing of the Incident Spectra. The depth-dose distributions reported in the text and summarized in this appendix were obtained using NMTC with energy and angular biasing of the incident source distributions incorporated into the calculations. The unbiased source distribution for incident Van Allen belt and solar-flare spectra may be expressed in the form

$$J(E,\vec{\Omega}) = \Phi_{o} G(E,\vec{\Omega}) , \qquad (A3.1)$$

where

 $J(E, \overrightarrow{\Omega})$ = the incident source particle current,

 Φ_{O} = a normalization constant,

 $G(E, \vec{\Omega}) = F(E, \mu, \phi) =$ the unbiased probability density function (pdf)

for source particles having energy E and

directions $\mu = \cos \theta$ and ϕ .

The unbiased pdf is normalized so that

$$\int_{E_{\min}}^{E_{\max}} \int_{0}^{1} \int_{0}^{2\pi} dE \ d\mu \ d\phi \ F(E,\mu,\phi) = 1$$
 (A3.2)

for all particles having energies greater than the cutoff energy E_{\min} (see Sections 2.1.5 and 2.2.2).

Letting $\Phi(E)$ be the omnidirectional (over 4π) flux spectrum, then

$$J(E, \vec{\Omega}) = \Phi(E) \left(\frac{\mu}{2}\right) \left(\frac{1}{2\pi}\right) . \tag{A3.3}$$

Integrating Eq. A3.3 over all directions and over all particle energies above the cutoff energy E leads to the normalization constant Φ_0 ; that is

$$\Phi_{0} = \int_{E_{min}}^{E_{max}} dE \Phi(E) \int_{0}^{1} d\mu \frac{\mu}{2} \int_{0}^{2\pi} d\phi \frac{1}{2\pi} = \frac{\Psi(E_{min}) - \Psi(E_{max})}{4} , \quad (A3.4)$$

where

$$\Psi(E) = \int_{E}^{\infty} \Phi(E') dE'.$$

Introducing $F(E,\mu,\phi)=f(E)$ $g(\mu)$ $h(\phi)$, the unbiased source distribution may be written

$$J(E,\vec{\Omega}) = \frac{\Psi(E_{min}) - \Psi(E_{max})}{4} f(E) g(\mu) h(\phi),$$
 (A3.5)

where

$$\frac{\Psi(E_{min}) - \Psi(E_{max})}{4} = W_o = \text{the initial weight assigned to each source}$$

$$\text{particle,}$$

$$f(E) = \text{the pdf in energy} = \frac{\Phi(E)}{\Psi(E_{min}) - \Psi(E_{max})}$$

$$g(\mu) = \text{the pdf in polar angle} = 2\mu,$$

$$h(\phi) = \text{the pdf in azimuthal angle} = (2\pi)^{-1}.$$

To improve the statistical fluctuations in the dose distributions in the tissue, the source-particle energies and directions were not sampled from the pdf's given above but instead were sampled from biased distributions. These biased distributions were constructed so that those source-particle energies and directions that resulted in relatively large dose contributions were sampled more frequently. Statistical weighting fractions to account for the biasing were then applied to each source particle so that the original incident source spectral shape and normalization are preserved. For the energy biasing, the energy intervals, ΔE , and the sampling fractions for each energy interval used, p_E , are summarized in Table A3.1 for Van Allen belt and solar-flare spectra. The particle energy was selected uniformly within each energy interval according to the relation

$$E_S = E_U - R(E_U - E_L) = E_U - R(\Delta E)$$
, (A3.6)

where

 $E_S =$ the sampled energy,

E_U, E_L = the upper and lower bounds, respectively, of the energy interval in which the sample is taken,

R = a random number between 0 and 1.

TABLE A3.1

Energy Intervals and Sampling Fractions for Source
Energy Biasing in NMTC Calculations

Energy Interval (ΔE) (Mev)	Fraction (p _E)			
Van Allen Belt Spectra				
30 - 50	.10			
50 - 100	.13			
100 - 260	.35			
260 - 400	.25			
400 - 700	.12			
700 - 1000	.05			
Solar-Flare Spectra				
30 - 50	.05			
50 - 100	.05			
100 - 200	.30			
200 - 400	.50			
400 - 3000	.10			

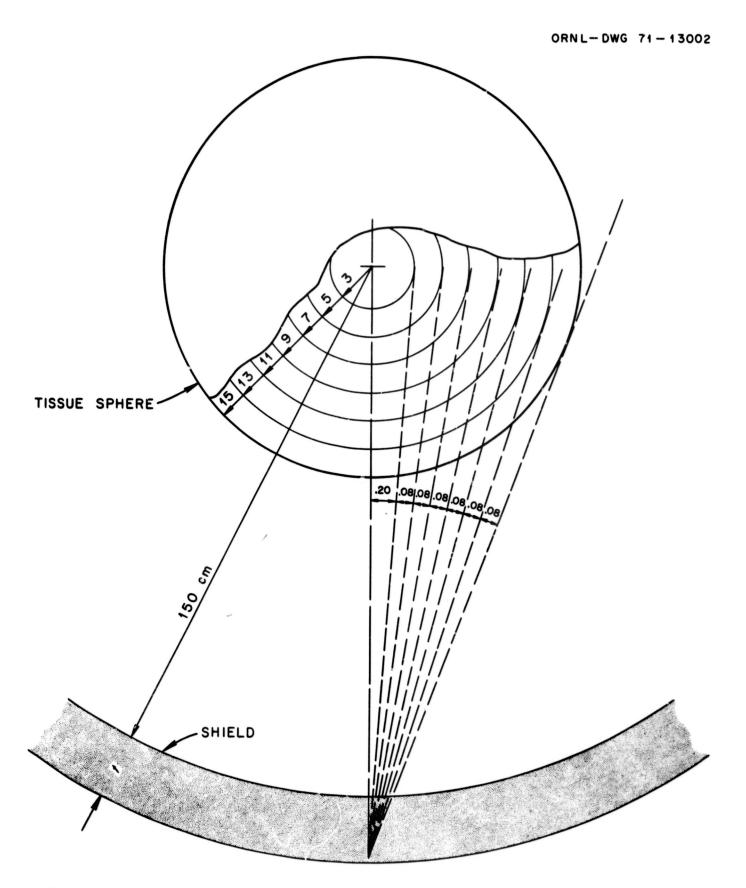


Fig. A3.1. Angular biasing intervals and selection fractions used with solar-flare and Van Allen belt spectra in the NMTC calculations.

The biased pdf in energy is now given by

$$f^*(E) = \frac{P_E}{\Delta E} , \qquad (A3.7)$$

and Eq. A3.5 may be rewritten as

$$J(E, \vec{\Omega}) = W_0 \left[\frac{f(E)}{f^*(E)} \right] f^*(E) g(\mu) h(\phi) , \qquad (A3.8)$$

where

$$\left[\frac{f(E)}{f^*(E)}\right] = W_E =$$
 the weight factor due to energy biasing.

Then

$$J(E, \vec{\Omega}) = W_O W_E f^*(E) g(\mu) h(\phi) . \qquad (A3.9)$$

Angular biasing of the incident spectra was accomplished using the scheme illustrated in Fig. A3.1. The angular intervals, $\Delta\mu$, and the sampling fractions, p_{μ} , for samples within the solid angle subtended by the tissue sphere were computed for each shield thickness. This was required since the inner radius of the shield was fixed. The angular intervals for particles having initial direction cosines toward the tissue sphere were computed using the relation

$$\mu_{j} = \cos \left[\arcsin \left(\frac{(2j+1) \text{ cm}}{150 \text{ cm} + \frac{t}{\rho}} \right) \right], \quad j = 0, 1, ...7,$$
(A3.10)

where

- j = an index corresponding to the fixed shell radii in the tissue sphere from which the angular biasing intervals are established for each shield thickness,
- t = the shield thickness (g/cm²),
- ρ = the density of the shield material (g/cm³).

TABLE A3.2

Angular Intervals and Sampling Fractions for Source Particle
Biasing in NMTC Calculations

Angular Interval (Δμ)	Sampling Fraction (p _µ)	
into sphere ^a	.68	
$\theta(\mu_7) - 7.5^{b}$.10	
7.5 - 12.5	.10	
12.5 - 17.5	.05	
17.5 - 22.5	.03	
22.5 - 30.0	.02	
30 - 60	.01	
60 - 90	.01	
	1.00	

a. See Fig. A3.1.

b. $\mu_{j=7}$ is determined from Eq. A3.10 for each shield thickness.

For calculational purposes, the angular intervals are defined by θ_j to θ_{j+1} . For particles directed into angular intervals beyond the sphere, the sampling fractions and angular intervals are summarized in Table A3.2. At the wider angles, the angular intervals were fixed for all shield thicknesses

Particles were selected uniformly within each angular interval according to the formula

$$\mu' = \mu_{j} - R(\mu_{j} - \mu_{j+1}) = \mu_{j} - R \Delta \mu$$
 (A3.11)

The biased pdf in polar angle can now be written

$$g^*(\mu) = \frac{P_{\mu}}{\Delta \mu} ,$$

and Eq. A3.9 may be written

$$J(E, \vec{\Omega}) = W_0 W_E W_u f^*(E) g^*(\mu) h(\phi)$$
, (A3.12)

where

$$W_{\mu} = \begin{bmatrix} g(\mu) \\ g^{*}(\mu) \end{bmatrix} = \begin{bmatrix} 2\mu & \Delta\mu \\ P_{\mu} \end{bmatrix} = \text{the weight factor due to direction}$$
 biasing interval $\Delta\mu$ about μ .

Since all source particles were uniformly sampled in the azimuthal angles, $h^*(\phi) = h(\phi)$.

A3.1.3 Results of the Calculations for Incident Van Allen Belt and Solar-Flare Proton Spectra

All of the calculated particle contributions to the absorbed-dose and dose-equivalent distributions obtained using NMTC for the incident Van Allen belt and solar-flare proton spectra are presented in Figs. A3.2 through A3.41. For all of the results, the geometry is that given in Fig. 3.1 where $r_T = 15 \text{ g cm}^{-2}$. In the distributions, the contributions to the dose include those from primary protons as well as secondary protons, heavy nuclei, charged pions, photons from neutral pions, electrons, positrons, photons, and muons. Additional details of the mechanisms leading to these contributions were discussed in Section 6.2.

For each incident Van Allen belt spectrum, the absorbed-dose rate (rad/day) and the dose-equivalent rate (rem/day) are given in Figs. A3.2 to A3.19 as a function of depth in the tissue for the particle types given above. For the incident solar flares, the absorbed-dose (rad) and dose-equivalent (rem) distributions are given in Figs. A3.20 to A3.41.

The data are presented for the Van Allen spectra for increasing orbital altitudes, while the solar-flare results are given in order of decreasing characteristic rigidity. Where more than one shield thickness is reported for a given incident-particle spectrum, the results are given in order of increasing shield thickness.

It should be noted that all of the data are presented on 6-cycle semilogarithmic displays. This was done to avoid needless compression of the data. In some of the graphs, the histograms for those particles making small contributions to the dose are not continuous and gaps may appear since the dose in that interval falls below the smallest value in the dose scale.

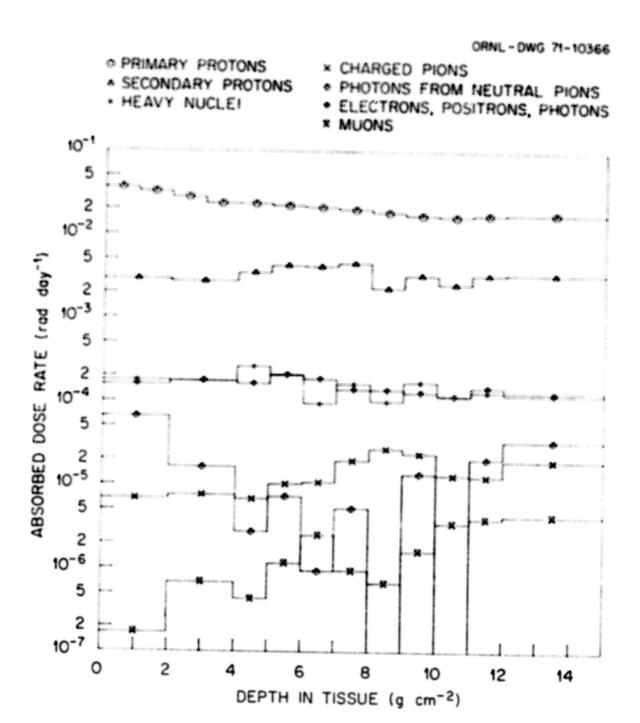


Fig. A3.2. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick aluminum shield.

- O PRIMARY PROTONS
- SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- · PHOTONS FROM NEUTRAL PIONS
- · ELECTRONS, POSITRONS, PHOTONS
- * MUONS

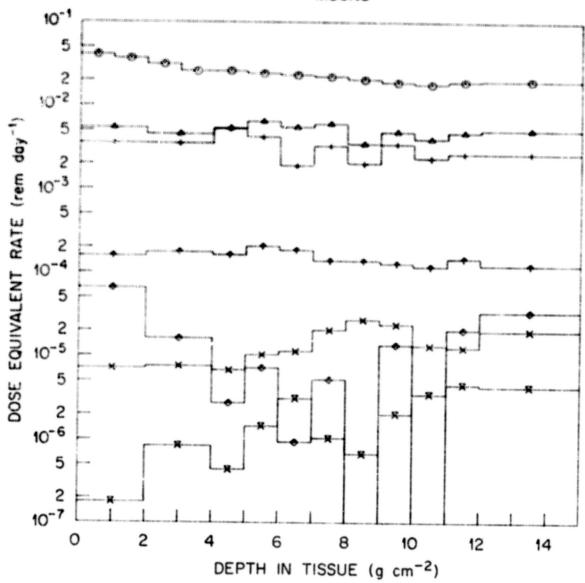


Fig. A3.3. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue who a Van Allen belt spectrum corresponding to an altitude of 240 nautical moles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick aluminum shield.

- O PRIMARY PROTONS
- · SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- *** MUONS**

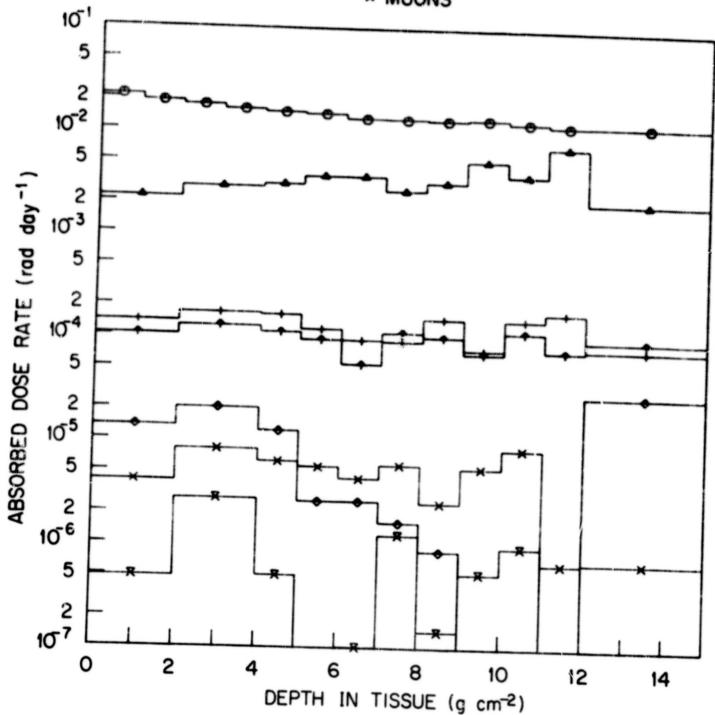


Fig. A3.4. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick polyethylene shield.

- O PRIMARY PROTONS
- SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- *** MUONS**

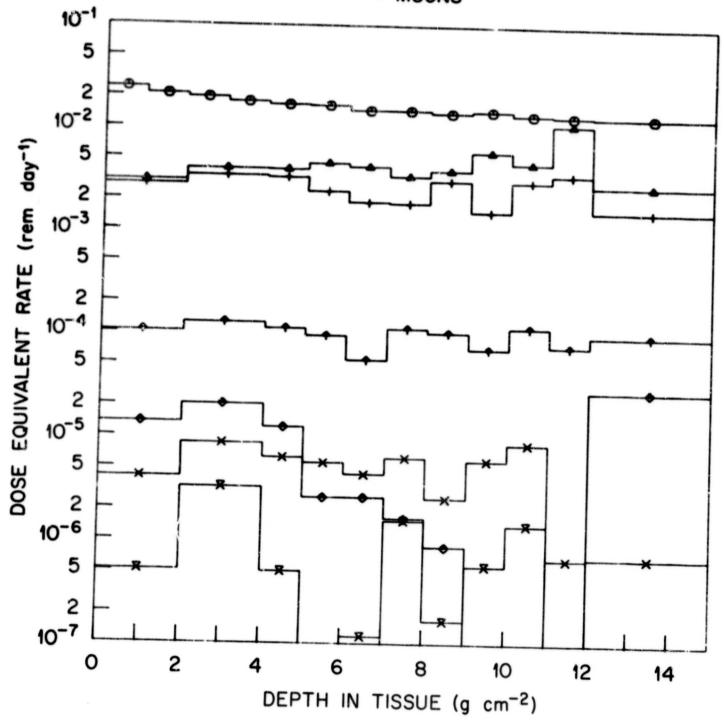


Fig. A3.5. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick polyethylene shield.

- **O PRIMARY PROTONS**
- SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- * ELECTRONS, POSITRONS, PHOTONS
- MUONS

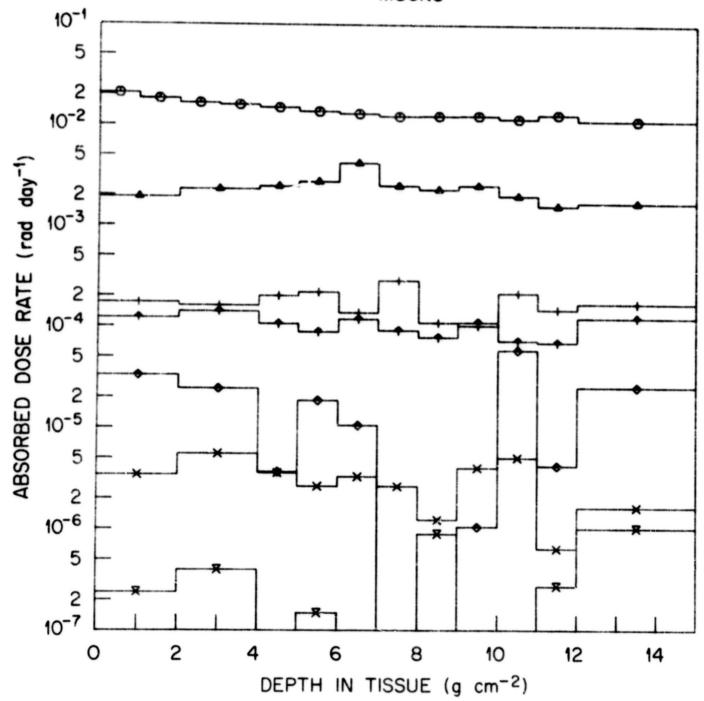


Fig. A3.6. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° is isotropically incident on a $35\text{-g-cm}^{-2}\text{-thick}$ copper shield.

- PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- ◆ ELECTRONS, POSITRONS, PHOTONS
- **× MUONS**

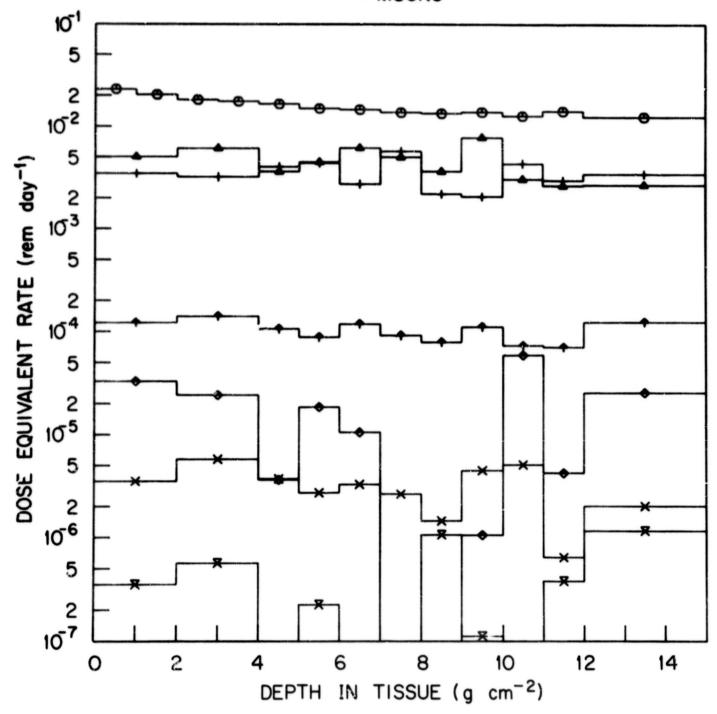


Fig. A3.7. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 240 nautical miles and an orbital inclination of 30° is isotropically incident on a 35-g-cm⁻²-thick copper shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- O PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- *** MUONS**

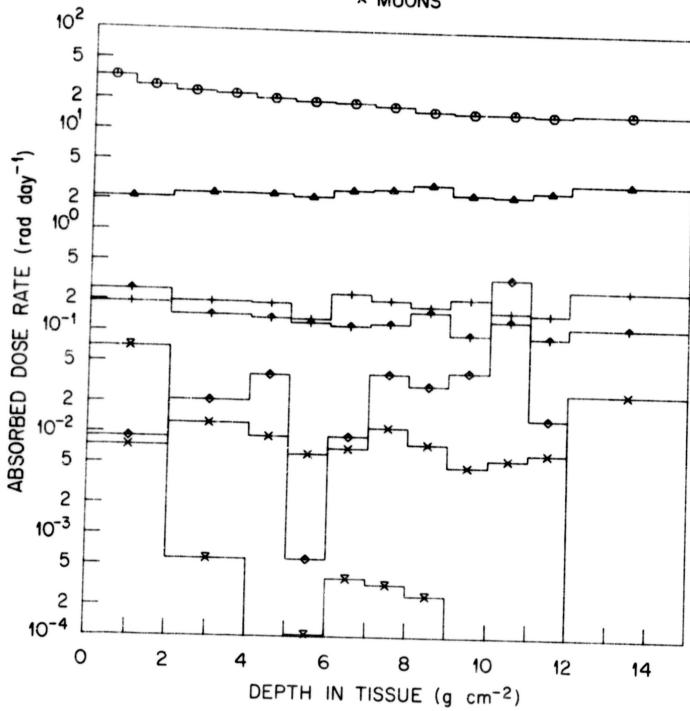


Fig. A3.8. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 1500 nautical miles and an orbital inclination of 30° is isotropically incident on a 5-g-cm⁻²-thick polyethylene shield.

- **O PRIMARY PROTONS**
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- ◆ ELECTRONS, POSITRONS, PHOTONS
- × MUONS

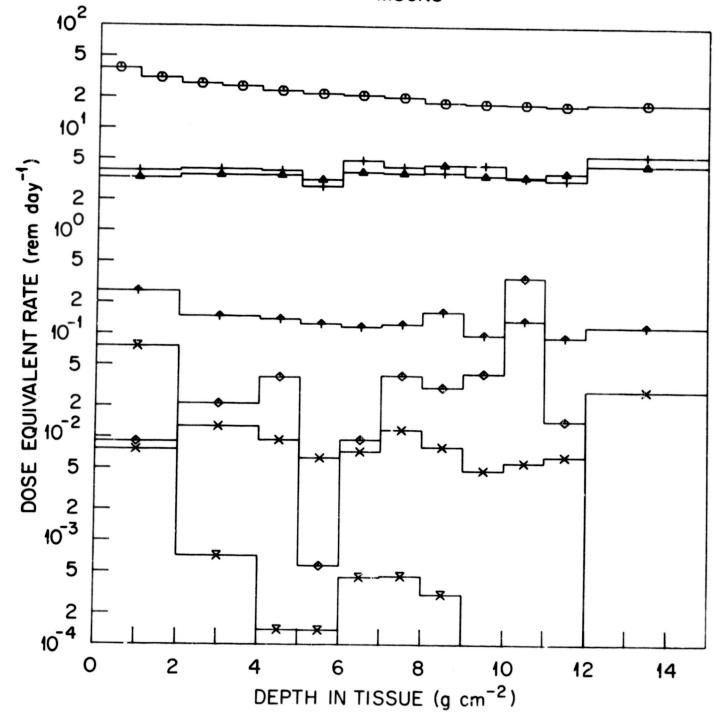


Fig. A3.9. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 1500 nautical miles and an orbital inclination of 30° is isotropically incident on a 5-g-cm⁻²-thick polyethylene shield.

- O PRIMARY PROTONS
- ▲ SECONDARY FROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS

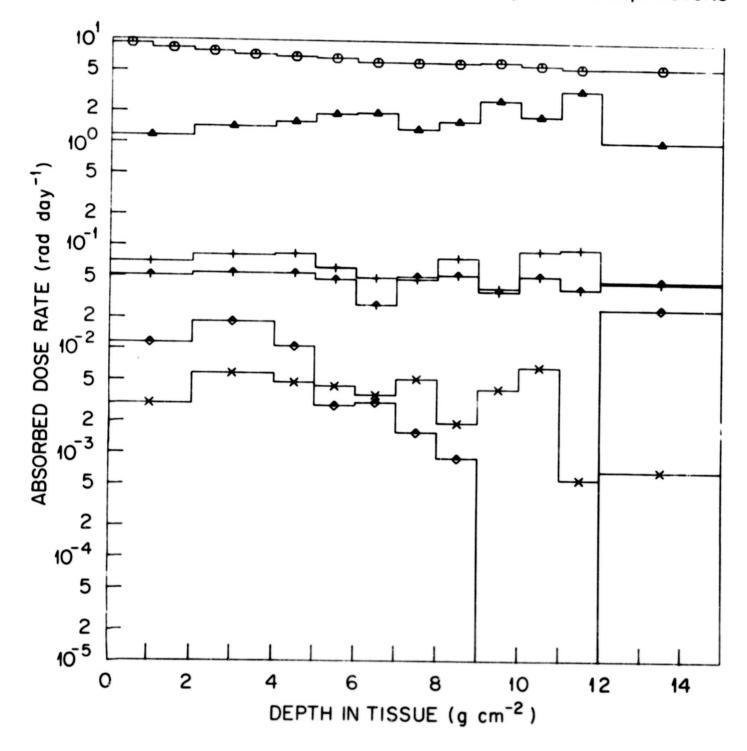


Fig. A3.10. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 1500 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick polyethylene shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- * ELECTRONS, POSITRONS, PHOTONS

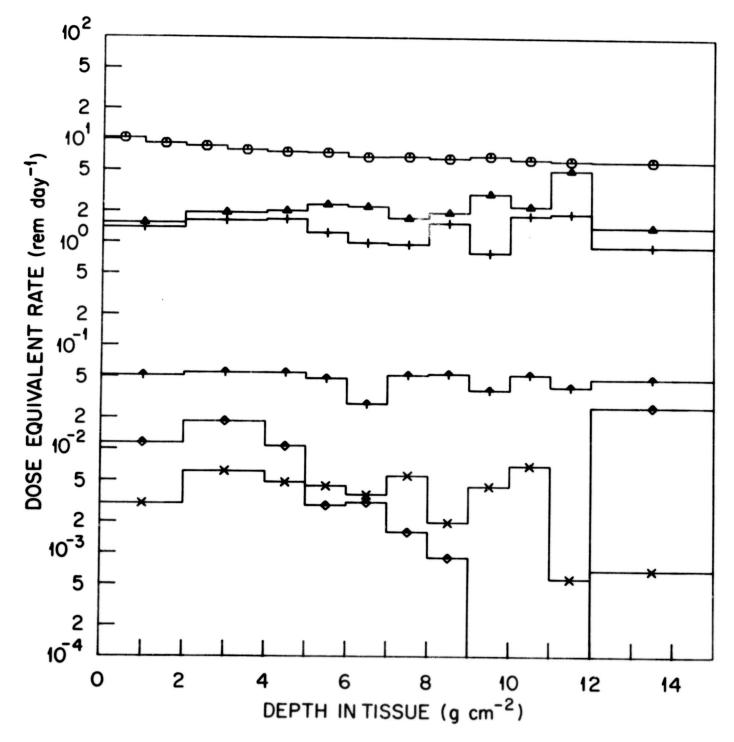


Fig. A3.11. Contributions to the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 1500 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick polyethylene shield.

- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- ♦ PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

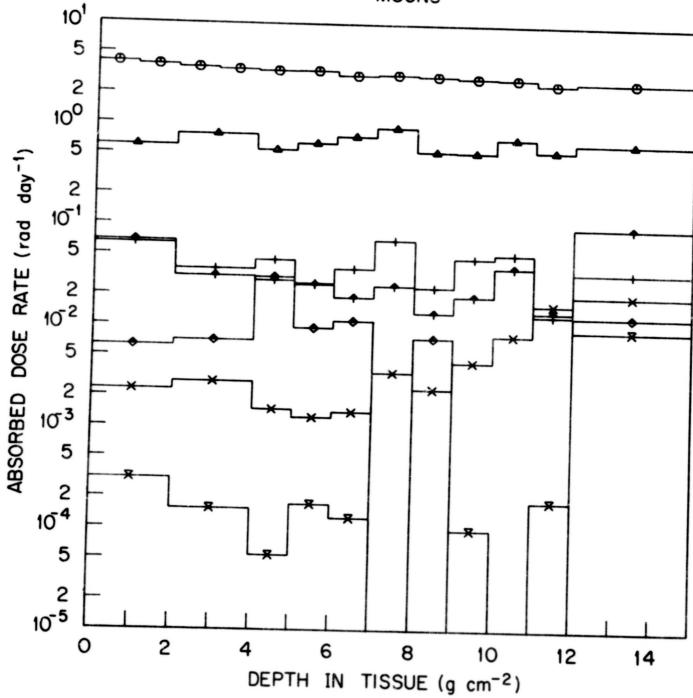


Fig. A3.12. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 1500 nautical miles and an orbital inclination of 30° is isotropically incident on a $35\text{-g-cm}^{-2}\text{-thick}$ polyethylene shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

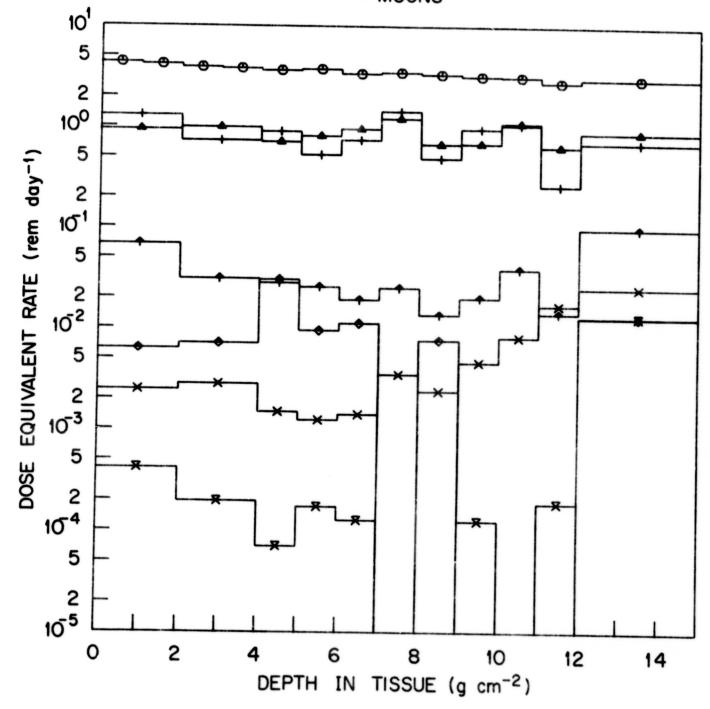


Fig. A3.13. Contributions to the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 1500 nautical miles and an orbital inclination of 30° is isotropically incident on a $35\text{-g-cm}^{-2}\text{-thick}$ polyethylene shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

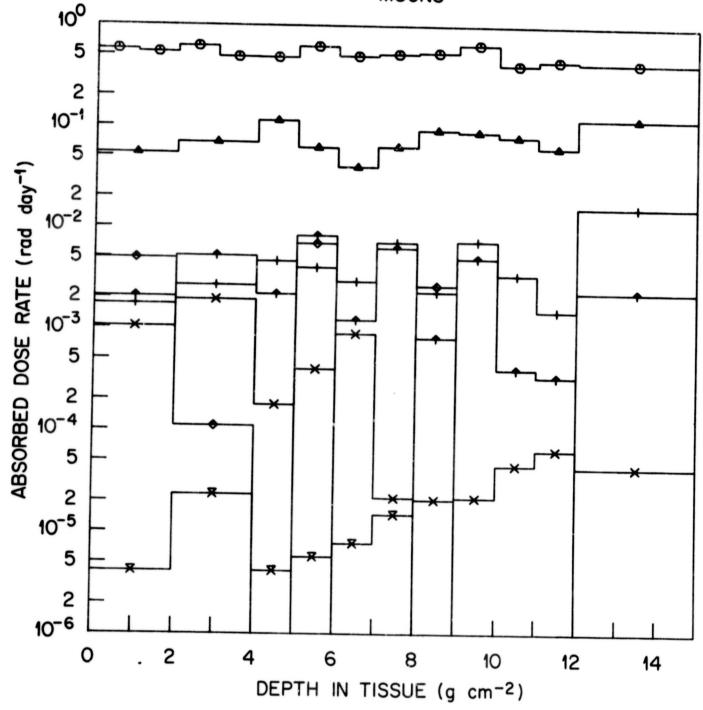


Fig. A3.14. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 1500 nautical miles and an orbital inclination of 30° is isotropically incident on a 75-g-cm⁻²-thick polyethylene shield.

- PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- ♦ PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

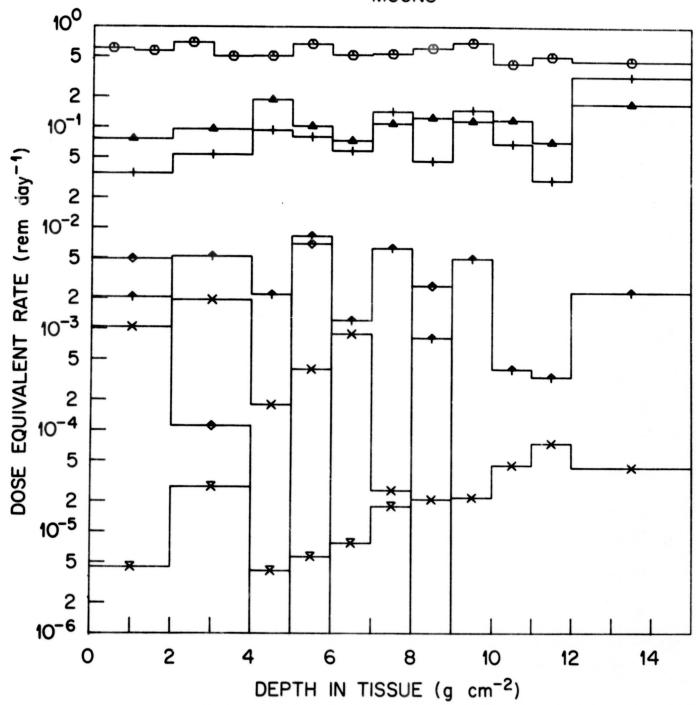


Fig. A3.15. Contributions to the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 1500 nautical miles and an orbital inclination of 30° is isotropically incident on a 75-g-cm⁻²-thick polyethylene shield.

- O PRIMARY PROTONS
- **△** SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

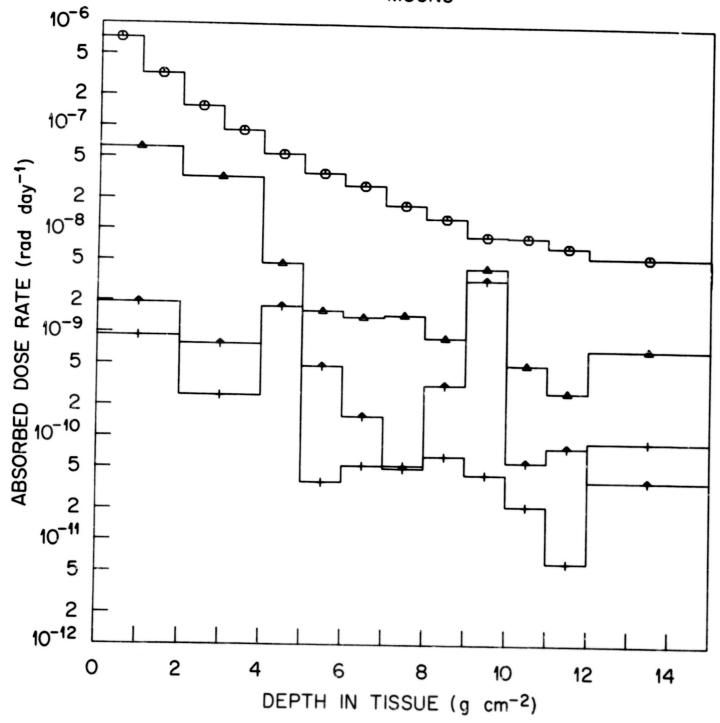


Fig. A3.16. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 6000 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick aluminum shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- → ELECTRONS, POSITRONS, PHOTONS
- × MUONS

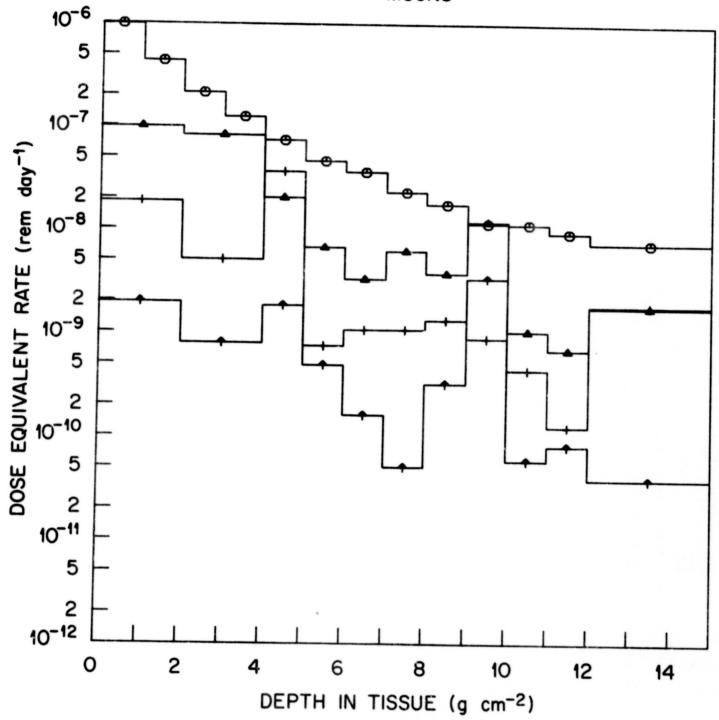


Fig. A3.17. Contributions to the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 6000 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick aluminum shield.

- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- **× MUONS**

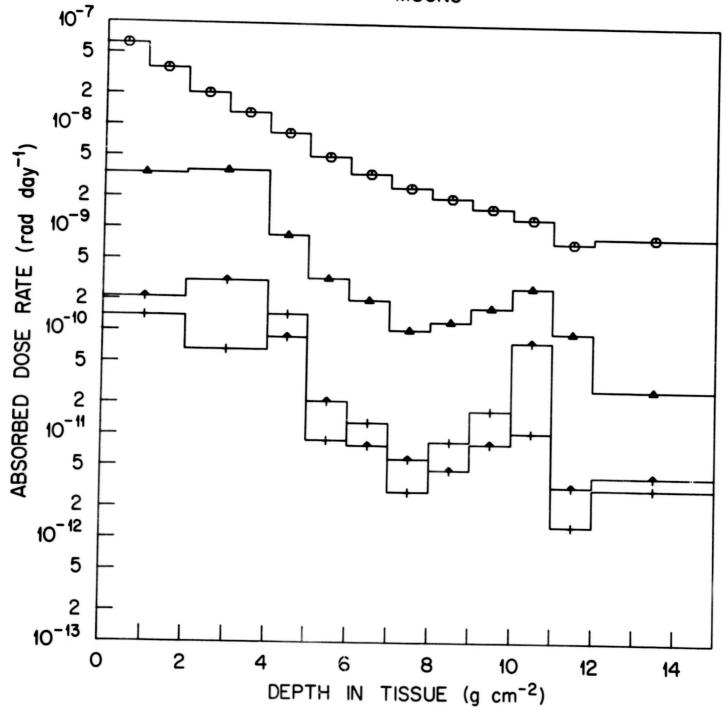


Fig. A3.18. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 6000 nautical miles and an orbital inclination of 30° is isotropically incident on a 20-g-cm^{-2} -thick polyethylene shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- ♦ PHOTONS FROM NEUTRAL PIONS
- * ELECTRONS, POSITRONS, PHOTONS
- × MUONS.

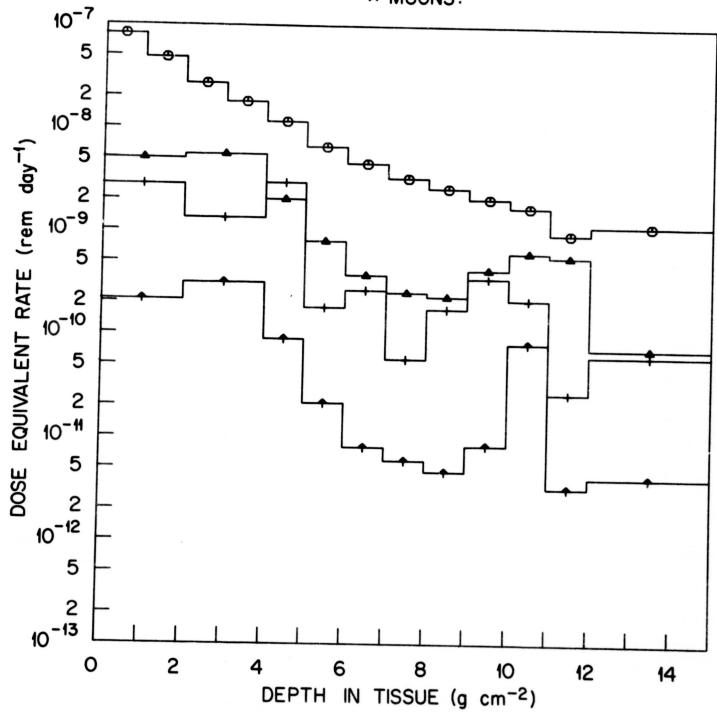


Fig. A3.19. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a Van Allen belt spectrum corresponding to an altitude of 6000 nautical miles and an orbital inclination of 30° is isotropically incident on a $20\text{-g-cm}^{-2}\text{-thick}$ polyethylene shield.

- **O PRIMARY PROTONS**
- **△** SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- **PHOTONS FROM NEUTRAL PIONS**
- * ELECTRONS, POSITRONS, PHOTONS
- × MUONS

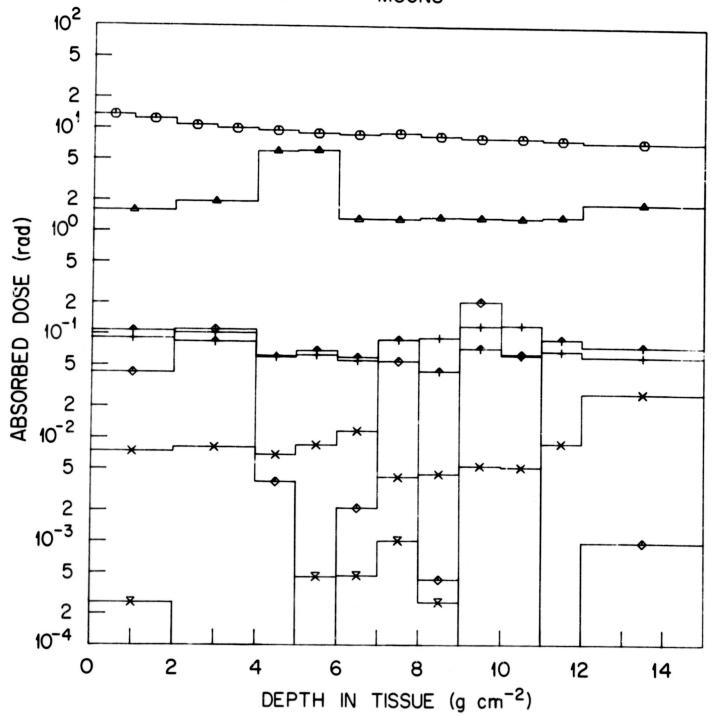


Fig. A3.20. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar—lare proton spectrum with a characteristic rigidity of 200 MV is isotropically incident on a 20-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- ♦ PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

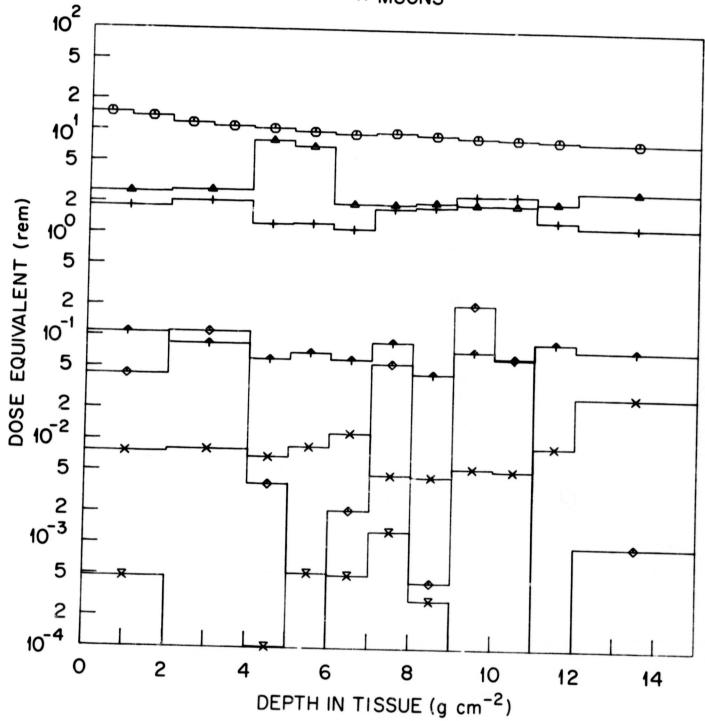


Fig. A3.21. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 200 MV is isotropically incident on a 20-g-cm⁻²-thick aluminum shield.

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- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- * ELECTRONS, POSITRONS, PHOTONS
- × MUONS

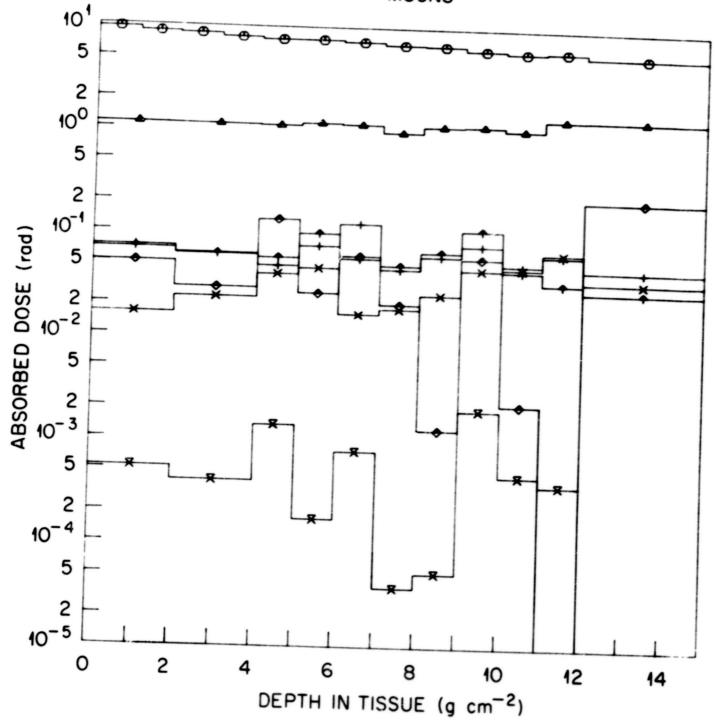


Fig. A3.22. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 200 MV is isotropically incident on a 20-g-cm⁻²-thick polyethylene shield.

- PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- ♦ PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

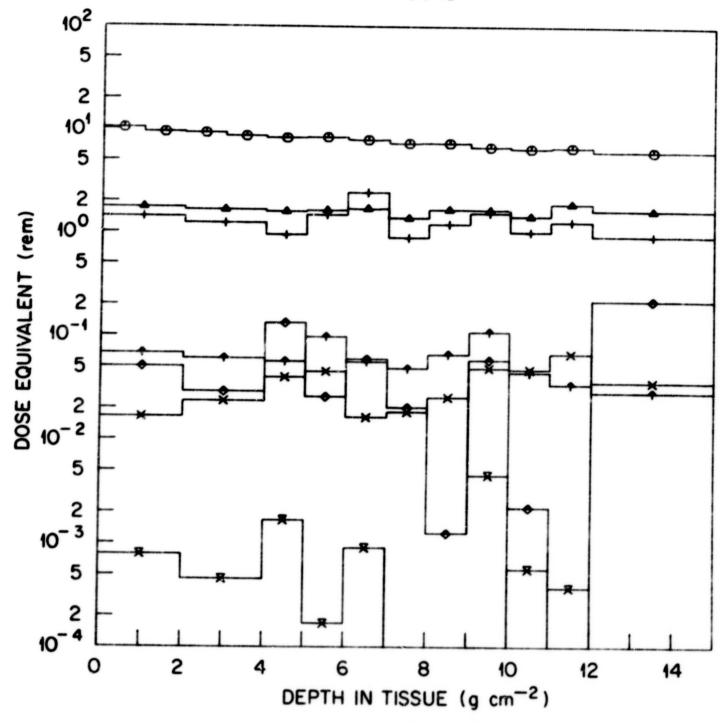


Fig. A3.23. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 200 MV is isotropically incident on a 20-g-cm⁻²-thick polyethylene shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLE!
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

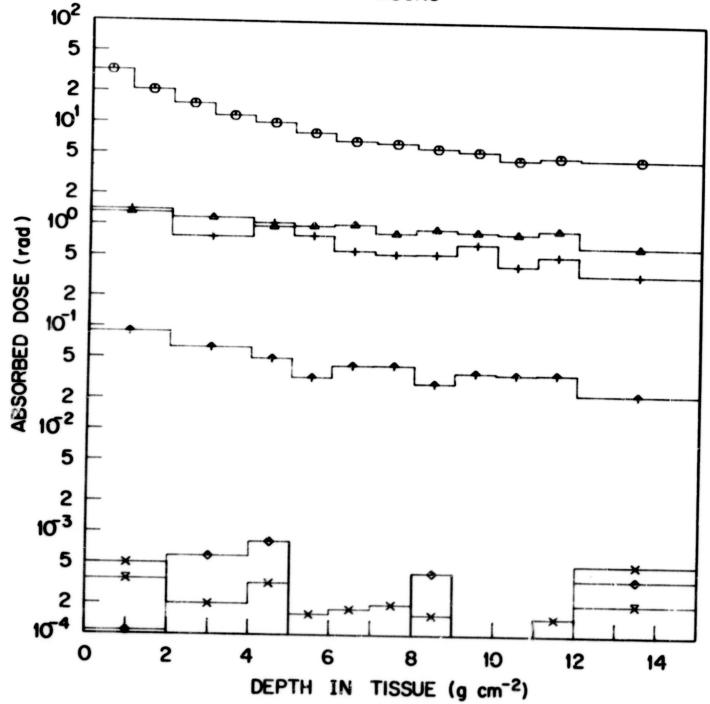


Fig. A3.24. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 5-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- ♦ PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- *** MUONS**

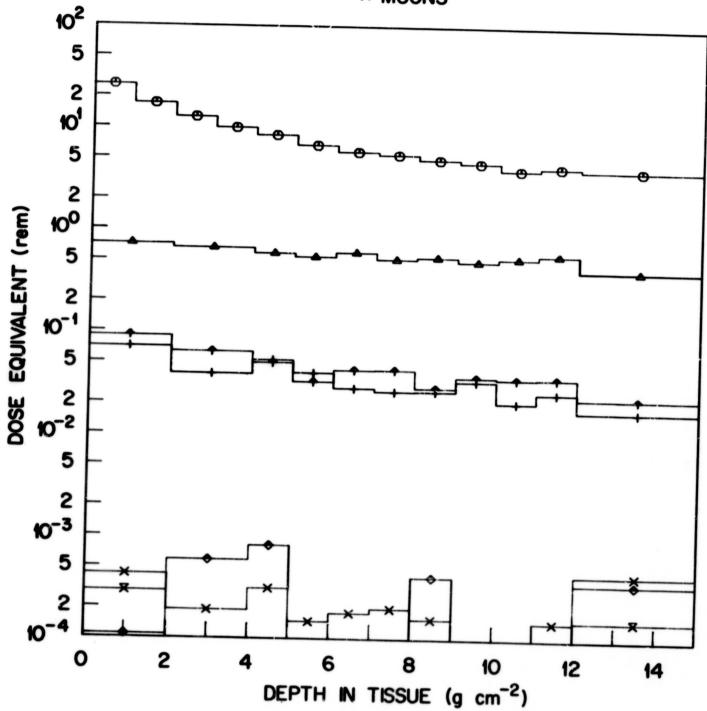


Fig. A3.25. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 5-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

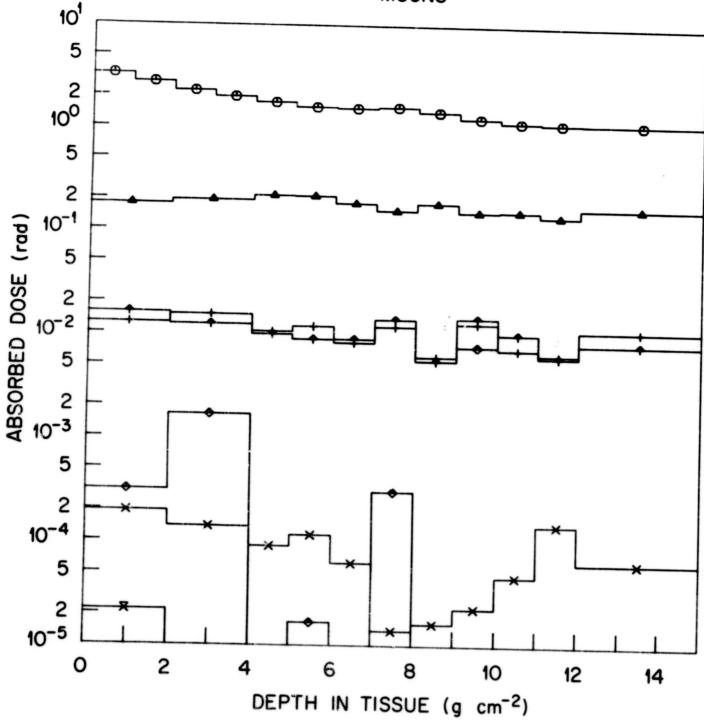


Fig. A3.26. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 20-g-cm⁻²-thick aluminum shield.

- **O PRIMARY PROTONS**
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- → ELECTRONS, POSITRONS, PHOTONS
- × MUONS

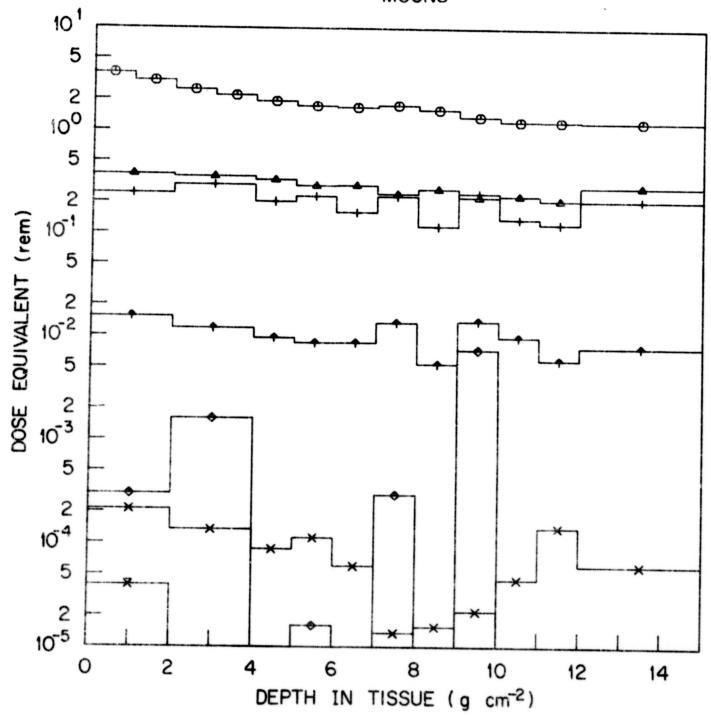


Fig. A3.27. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 20-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- **△** SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

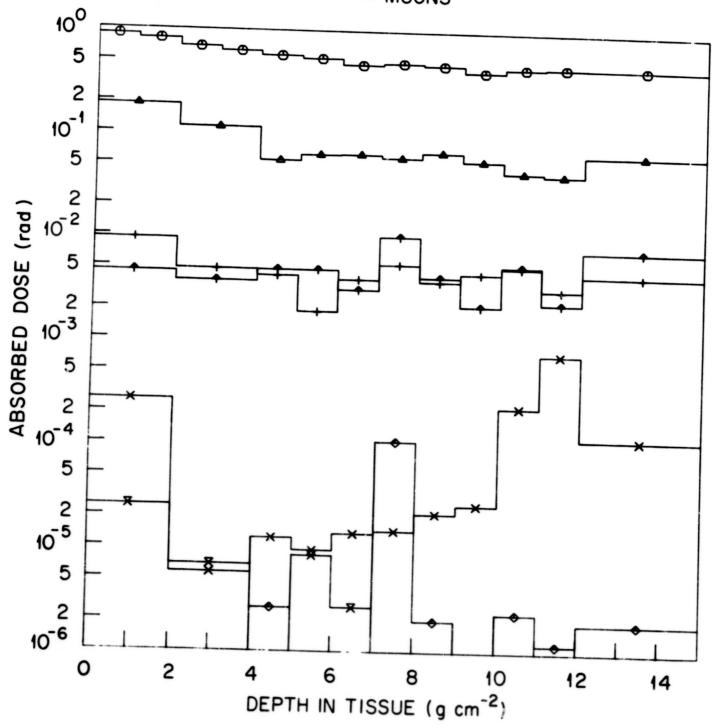


Fig. A3.28. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 35-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

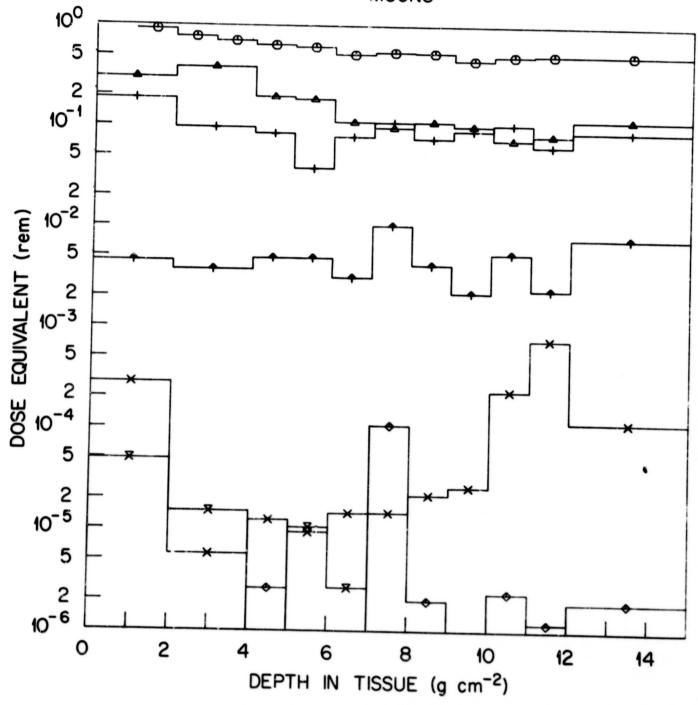


Fig. A3.29. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 35-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

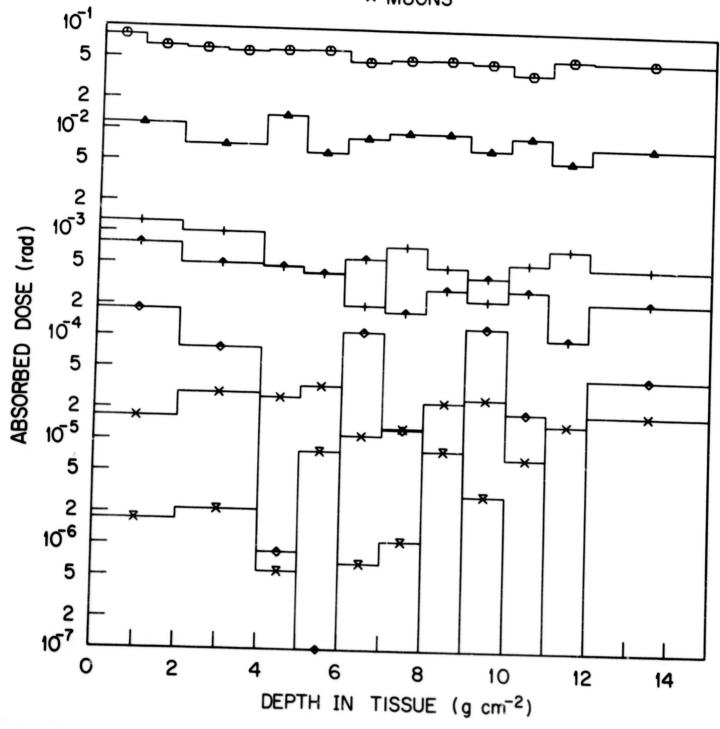


Fig. A3.30. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 75-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- * ELECTRONS, POSITRONS, PHOTONS
- **×** MUONS

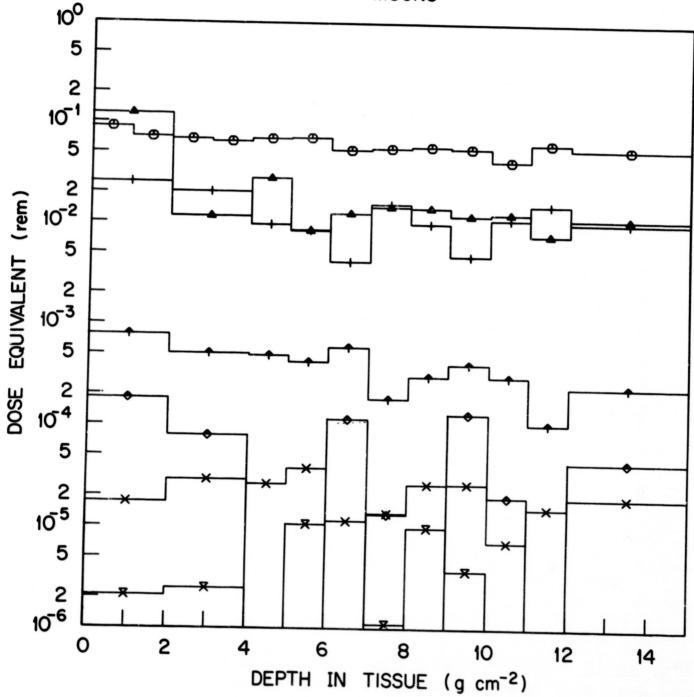


Fig. A3.31. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 75-g-cm⁻²-thick aluminum shield.



- △ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

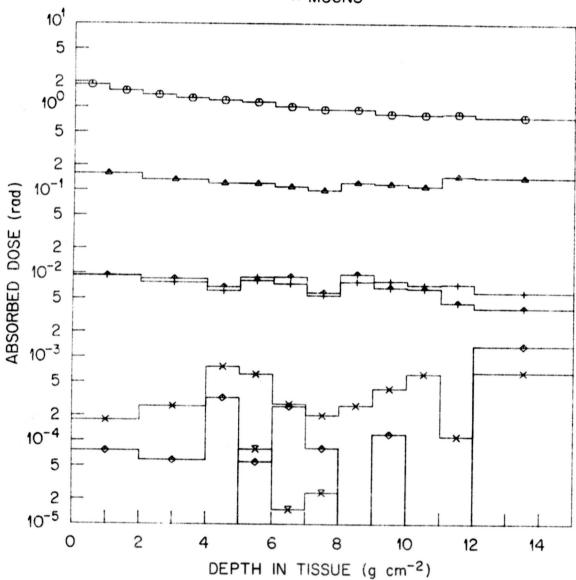


Fig. A3.32. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100~MV is isotropically incident on a 20-g-cm^{-2} -thick polyethylene shield.

O PRIMARY PROTONS

△ SECONDARY PROTONS

+ HEAVY NUCLEI

× CHARGED PIONS

* PHOTONS FROM NEUTRAL PIONS

+ ELECTRONS, POSITRONS, PHOTONS

× MUONS

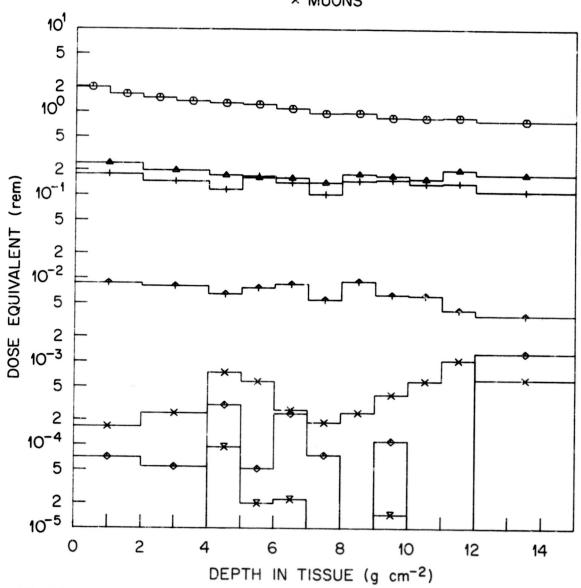


Fig. A3.33. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of $100~\rm MV$ is isotropically incident on a $20-\rm g-cm^{-2}$ -thick polyethylene shield.

- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- * ELECTRONS, POSITRONS, PHOTONS
- × MUONS

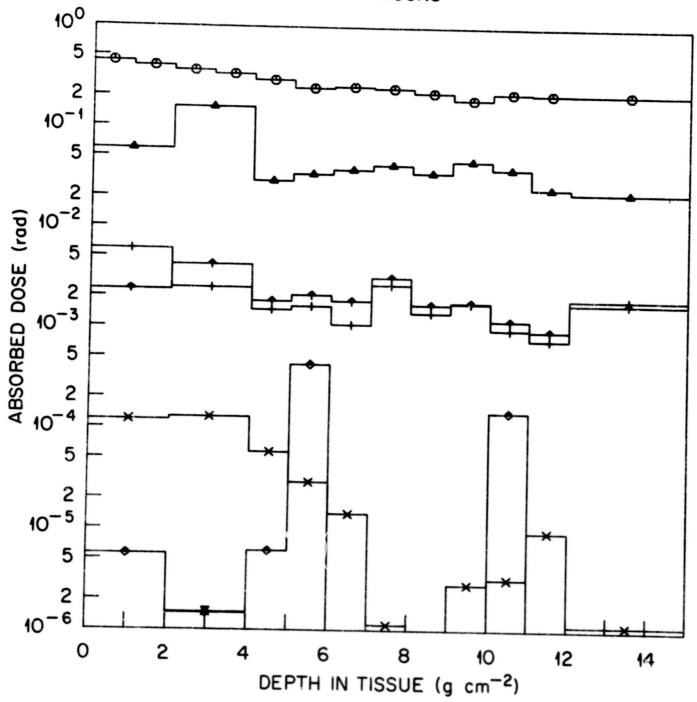


Fig. A3.34. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 35-g-cm⁻²-thick polyethylene shield.

- **O PRIMARY PROTONS**
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

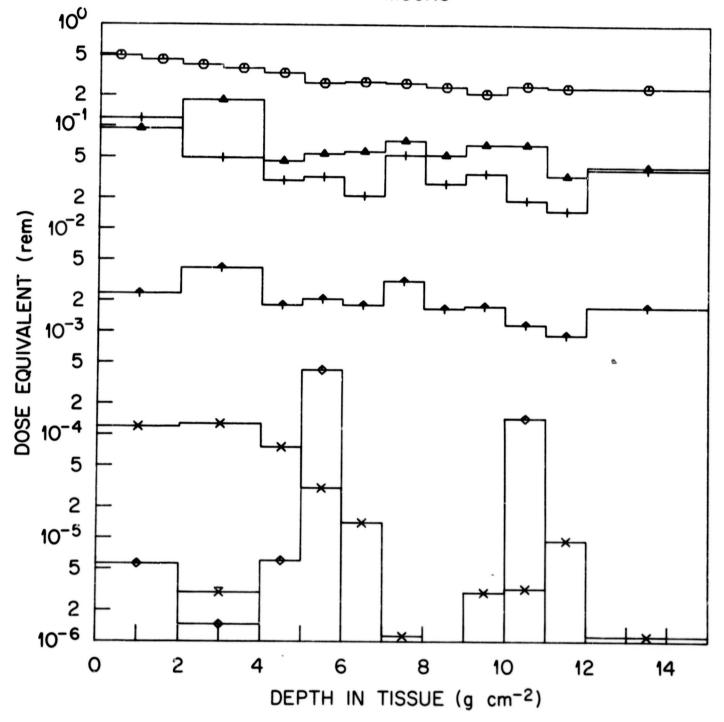


Fig. A3.35. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 35-g-cm⁻²-thick polyethylene shield.

- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- O PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS

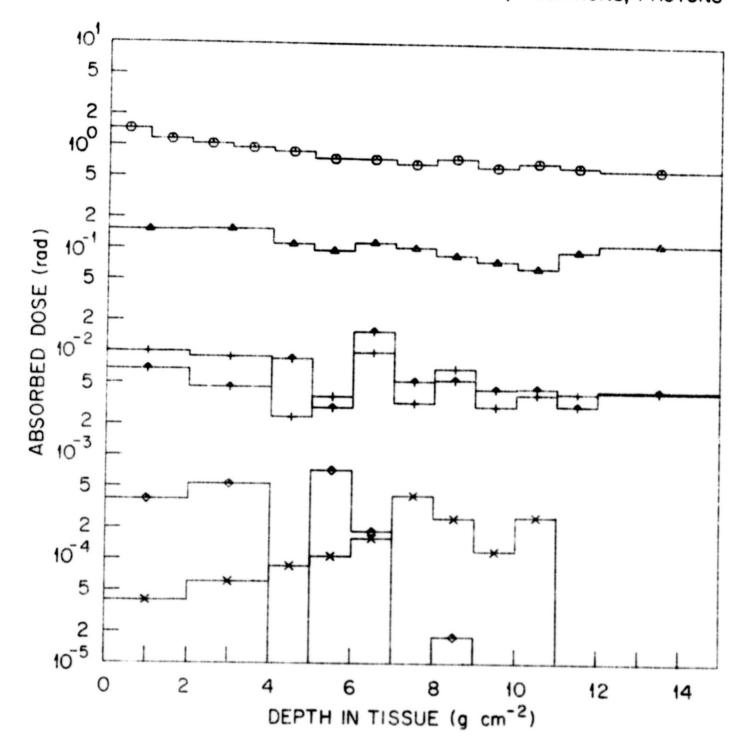


Fig. A3.36. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 35-g-cm⁻²-thick copper shield.

- PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

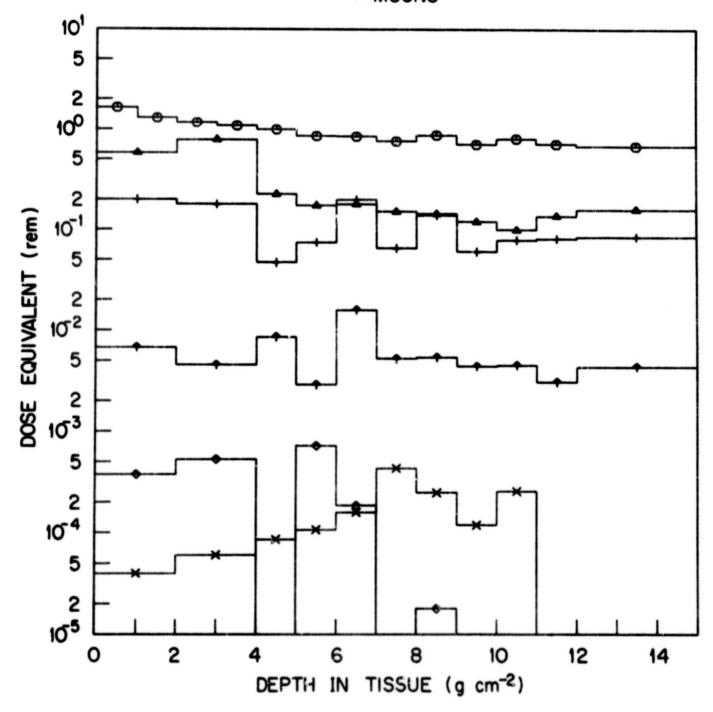


Fig. A3.37. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 100 MV is isotropically incident on a 35-g-cm⁻²-thick copper shield.

- **O PRIMARY PROTONS**
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- ♦ PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- **× MUONS**

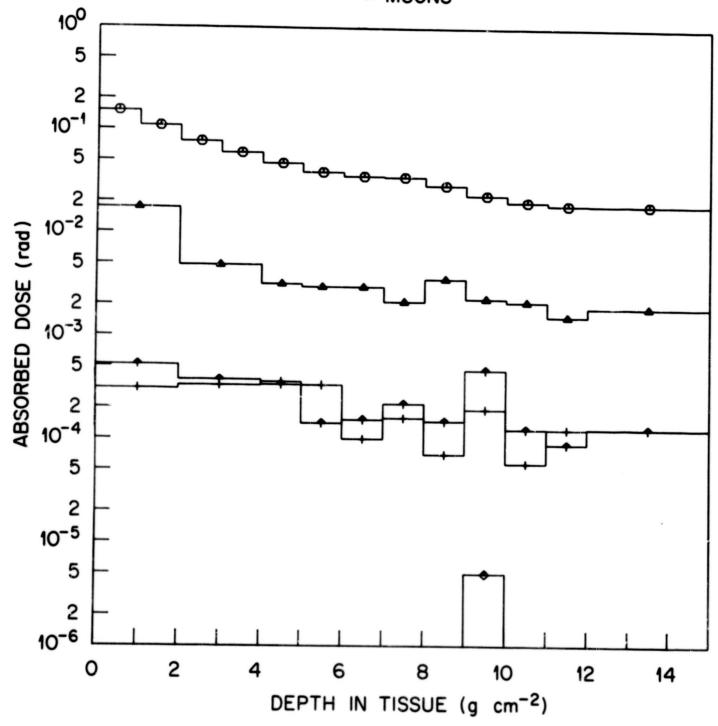


Fig. A3.38. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 50 MV is isotropically incident on a 20-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- **× MUONS**

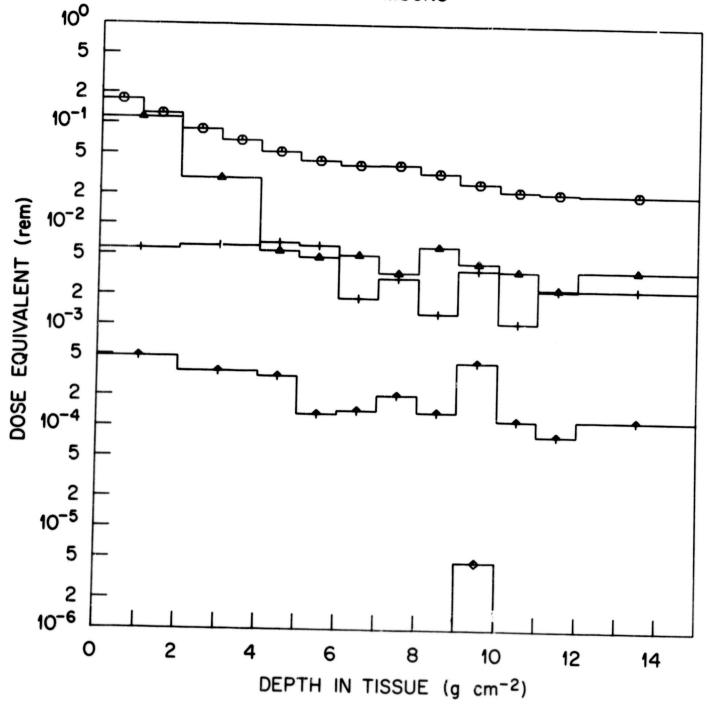


Fig. A3.39. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 50 MV is isotropically incident on a 20-g-cm⁻²-thick aluminum shield.

- O PRIMARY PROTONS
- ▲ SECONDARY PROTONS
- + HEAVY NUCLEI
- × CHARGED PIONS
- * PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- **X** MUONS

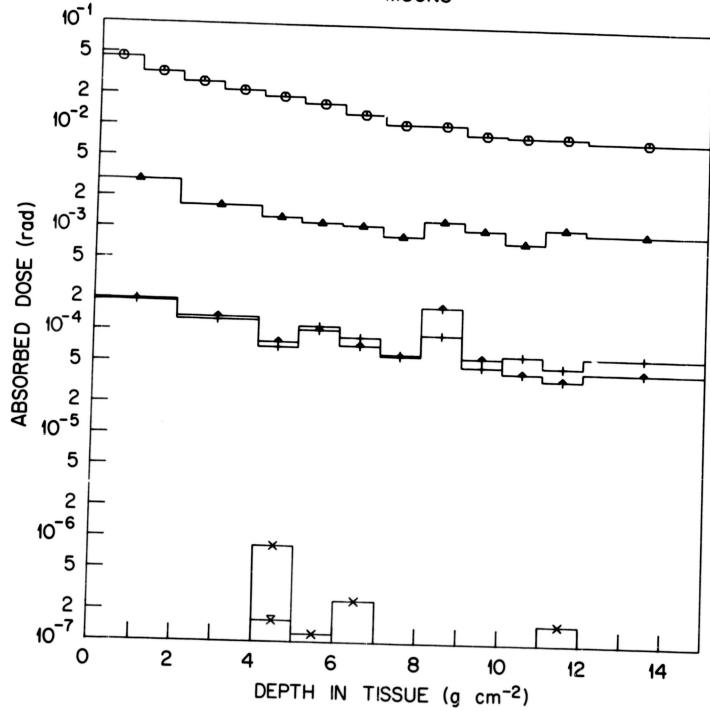


Fig. A3.40. Contributions from the various types of particles to the absorbed dose as a function of depth in tissue when a solar-flare proton on a 20-g-cm⁻²-thick polyethylene shield.

- O PRIMARY PROTONS
- **▲ SECONDARY PROTONS**
- + HEAVY NUCLEI
- × CHARGED PIONS
- PHOTONS FROM NEUTRAL PIONS
- + ELECTRONS, POSITRONS, PHOTONS
- × MUONS

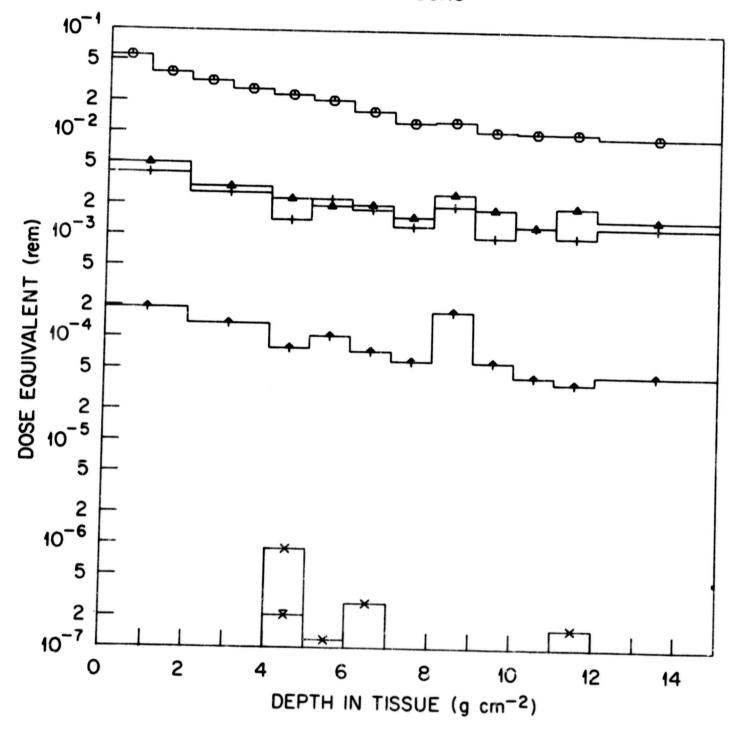


Fig. A3.41. Contributions from the various types of particles to the dose equivalent as a function of depth in tissue when a solar-flare proton spectrum with a characteristic rigidity of 50 MV is isotropically incident on a 20-g-cm⁻²-thick polyethylene shield.

A3.2 INCIDENT GALACTIC COSMIC-RAY PROTONS

When galactic cosmic-ray proton spectra are incident on the spacecraft shield, the secondary-particle contributions to the absorbed-dose and dose-equivalent distributions in tissue, which were previously introduced in Chapter 7, are given here. These distributions were obtained using the high-energy nucleon-meson transport code HETC⁷⁰ for the geometry shown in Fig. 3.1. HETC is discussed along with calculational methods for predicting high-energy (> 3 GeV) nucleon- and charged-pion-collision phenomena. Methods for sampling from the galactic cosmic-ray proton energy spectra and the angular biasing scheme used in the calculations are discussed.

A3.2.1 The High-Energy Transport Code HETC

The high-energy transport code HETC⁷⁰ is a high-energy version (> 3 GeV) of the nucleon-meson transport code NMTC discussed in Section A3.1.1. HETC simulates the transport of nucleons and pions in exactly the same manner as does NMTC with two major exceptions. Above the NMTC energy limits, ^{69,92,104} corresponding to 3.5 GeV for nucleons and 2.5 GeV for charged pions, an extrapolation method¹⁰⁹ is used to calculate the nonelastic nucleon-nucleus and charged-pion-nucleus collisions (excluding hydrogen), while an analytical procedure¹¹⁵ is used to describe the elastic and nonelastic nucleon- and charged-pion-hydrogen collisions.

The differential particle spectra resulting from nonelastic nucleonand charged-pion-nucleus collisions (excluding hydrogen) are treated using an extrapolation model due to Gabriel $et\ al.^{109}$ In this model, the data

^{115.} T. A. Gabriel, R. T. Santoro, and J. Barish, "A Calculational Method for Predicting Particle Spectra from High-Energy Nucleon and Pion Collisions (≥ 3 GeV) with Protons," Oak Ridge National Laboratory Report ORNL-TM-3615, 1971.

generated by the intranuclear-cascade code of Bertini¹¹⁶ at the upper energy limit are scaled to produce the differential cross sections for the particle-nucleus collision at the selected higher energy. Scaling is performed in the center-of-momentum system by assuming that each scaled and unscaled secondary-particle energy is related linearly with respect to the center-of-momentum energies of the incident scaled and unscaled particles. The additional assumption is made that the transverse momentum of each scaled secondary particle is the same as its unscaled counterpart. Weighting factors are used to conserve total energy and momentum.

The excitation of the residual nucleus from the high-energy collision is taken to be the same as the excitation of the residual nucleus in the unscaled collision. This assumption is justified to the extent that experimental data from high-energy reactions in emulsions indicate that the number of low-energy charged particles emitted is a slowly varying function of the incident-particle energy above ~ 10 GeV.

The elastic and nonelastic nucleon-proton and charged-pion-proton collisions above the NMTC energy limit are simulated using a calculational procedure. The nucleon-proton and charged-pion-proton interaction cross sections are taken from the compilations of Barashenkov⁸³ and of Bertini et al. These data are included in the calculational procedure through parametric-fitting techniques to obtain analytic functions. The elastic nucleon- and charged-pion-proton differential scattering cross sections are also obtained from parametric fits to experimental data.

^{116.} H. W. Bertini, M. P. Guthrie, and O. W. Hermann, "Instructions for the Operation of Codes Associated with MECC-3, a Preliminary Version of an Intranuclear-Cascade Calculation for Nuclear Reactions," Oak Ridge National Laboratory Report ORNL-4564, 1971; see also Computer Code Abstract "MECC-3, a Monte Carlo Intranuclear-Cascade Code for Medium-Energy (< 3500 MeV) Particle-Nucleus Collisions," Nucl. Sci. Eng. 46, 437 (1971).

Nonelastic nucleon and charged-pion spectra resulting from these collisions are obtained from modified Ranft-Borak nucleon- and pion-production distributions. The nonelastic collision events are computed from the Ranft-Borak p + p functions using assumptions for n + p and π^+ + p collisions. The details attendant to these assumptions are rigorous, and the reader is directed to Ref. 115 for further insight into the calculation.

For each collision event and for the average of many events, energy and nucleons are conserved and spectral shape is preserved over an angular interval from 0 to 45°. Standard sampling and storage techniques that can be employed to conserve these quantities are utilized to obtain the secondary-particle type, energy, and direction cosines that result from a specified collision.

A3.2.2 Details of the Transport Calculations

For the calculations of the depth-dose distributions arising from galactic cosmic-ray protons, the transport of nucleons, charged pions, and muons is handled in the same manner as that described in Section A3.1.2. For these calculations, however, the spatial distribution of the energy deposition due to electrons and positrons from muon decay and photons from π^0 decay is taken into account in an approximate manner 92 rather than assuming that this energy is deposited at the spatial point where the electrons, positrons, and photons are produced.

To realize improved statistical accuracy in the tissue sphere, splitting of both primary and secondary particles at the interface of the void and tissue sphere is utilized; i.e., a single incident particle having a large weight W is split and treated as n particles, each of reduced weight W/n.

^{117.} J. Ranft and T. Borak, "Improved Nucleon-Meson Cascade Calculations," National Accelerator Laboratory Report FN-193, 1100.0, 1969.

Angular and Energy Biasing of the Incident Spectrum. The angular biasing scheme for the galactic cosmic-ray proton calculations follows the same procedure as that given in Section A3.1.2. However, now only 34% of the incident particles are allowed to have initial direction cosines toward the tissue sphere. The angular intervals are derived from Eq. A3.10 and the sampling fractions for these intervals are one-half of those indicated in Fig. A3.1. The remaining 66% of the particles are directed into the angular intervals $\theta(\mu_7) - 45^{\circ}$ with $\rho_{\mu} = 0.40$ and 45 to 90° with $\rho_{\mu} = 0.26$.

For incident cosmic-ray protons, a quota sampling scheme is used to select from the energy spectra. In these calculations, the galactic proton energy spectra range from 30 MeV to 200 GeV. Following the notation of Section A3.1.2, the source-particle current may be written in the form given in Eq. A3.12; i.e.,

$$J(E, \overrightarrow{\Omega}) = W_O W_E W_{\mu} f^*(E) g^*(\mu) h(\phi)$$
,

where W_0 , W_μ , $g^*(\mu)$, and $h(\phi)$ have the same meanings as in Section A3.1.2. For quota sampling, the probability density function in energy is given by

$$f(E) = \frac{\phi(E)}{\phi(E_o)} .$$

Now, the biased pdf in energy is given by

$$f^*(E) = \frac{n_i}{\sum n_i} \left(\frac{1}{\Delta E_i} \right)$$
,

where

 $\frac{n_i}{\sum_{i=1}^{n}}$ = the probability that n particles are selected from the ith energy interval,

 $\frac{1}{\Delta E_i}$ = the probability that the particle has energy dE about E.

The values n_i and the corresponding energy intervals used are given in Table A3.3. Writing

 $W_E = \frac{f(E)}{f^*(E)}$ = the weight factor from energy biasing through quota sampling,

then

$$J(E, \stackrel{\rightarrow}{\Omega}) = W_0 W_E W_{\mu} f^*(E) g^*(\mu) h(\phi)$$

as before.

A3.2.3 Results of Calculations for Incident Galactic Cosmic-Ray Proton Spectra

The calculated particle contributions to the absorbed-dose-rate and dose-equivalent-rate distributions obtained using HETC for incident galactic cosmic-ray proton spectra are presented in Figs. A3.42 to A3.49. For all of the results, the geometry is that given in Fig. 3.1 where $\rm r_T=15~g~cm^{-2}$. In the distributions, the contributions to the dose rate include those from primary protons as well as from secondary protons, heavy nuclei, charged pions, photons from neutral pions, electrons, positrons, photons, and muons. Additional details of the mechanisms leading to these contributions may be found in Section 6.2.

The dose distributions are presented when galactic solar-minimum protons are incident on 5-, 20-, and 35-g-cm⁻²-thick aluminum shields (Figs. A3.42 to A3.47) and when galactic solar-maximum protons are incident on a 35-g-cm⁻²-thick aluminum shield (Figs. A3.48 and A3.49). The results are plotted on 4-cycle semilogarithmic displays to avoid compression of the data. In some of the graphs, gaps in the histograms may appear where contributions to the dose are smaller than the smallest value on the dose scale.

TABLE A3.3

Energy Intervals and Quota-Sampling Values for Energy Biasing of Galactic Cosmic-Ray Proton Spectra

Interval Number	Energy Interval (MeV)	n _i
1	30 - 100	10
2	100 - 500	40
3	500 - 1,000	20
4	1,000 - 3,000	9
5	3,000 - 6,000	6
6	6,000 - 10,000	5
7	10,000 - 30,000	4
8	30,000 - 60,000	3
9	60,000 - 100,000	2
10	100,000 - 200,000	1
		$\sum_{1}^{10} n_{i} = 100$

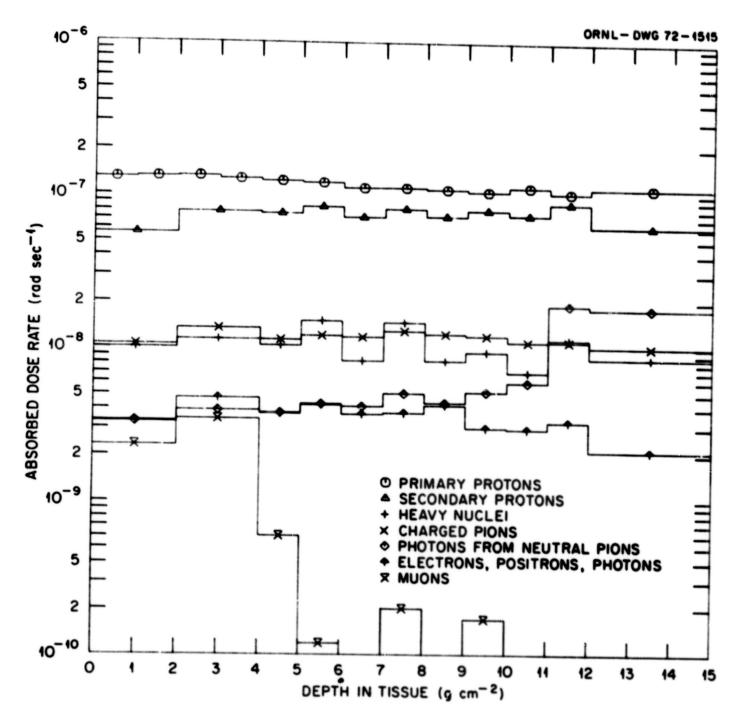


Fig. A3.42. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a galactic cosmic-ray solar-minimum proton spectrum is isotropically incident on a 5-g-cm⁻²-thick aluminum shield.

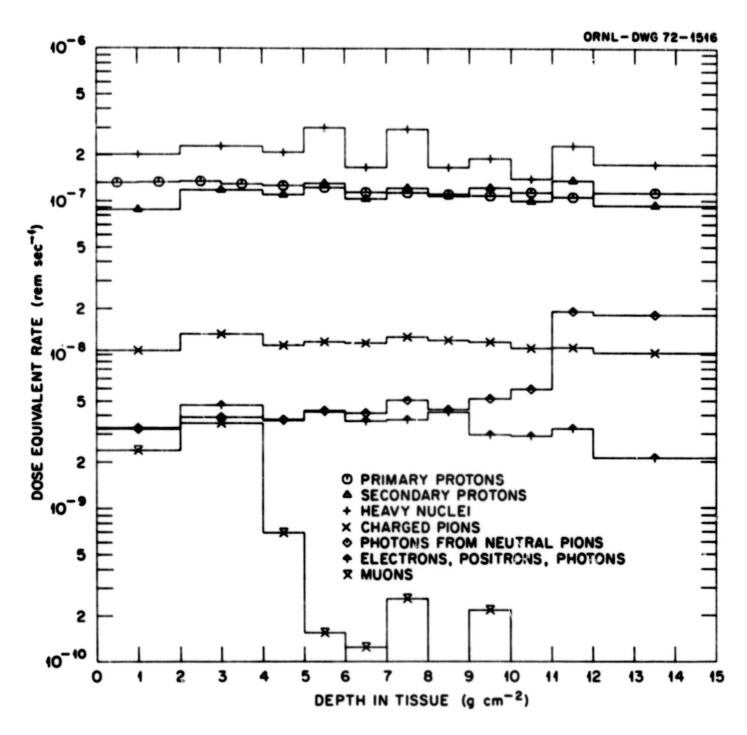


Fig. A3.43. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a galactic cosmic-ray solar-minimum proton spectrum is isotropically incident on a 5-g-cm⁻²-thick aluminum shield.

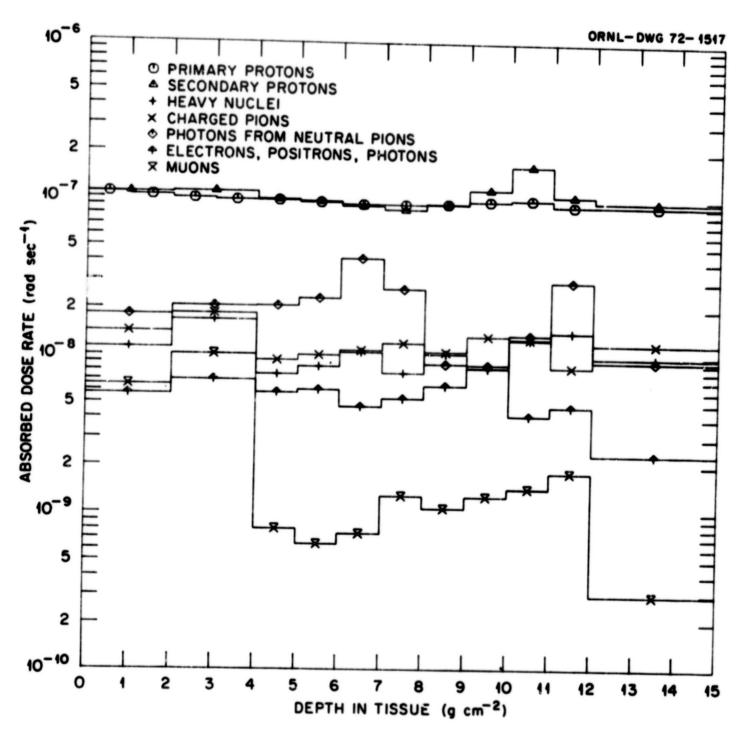


Fig. A3.44. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a galactic cosmic-ray solar-minimum proton spectrum is isotropically incident on a 20-g-cm⁻²-thick aluminum shield.

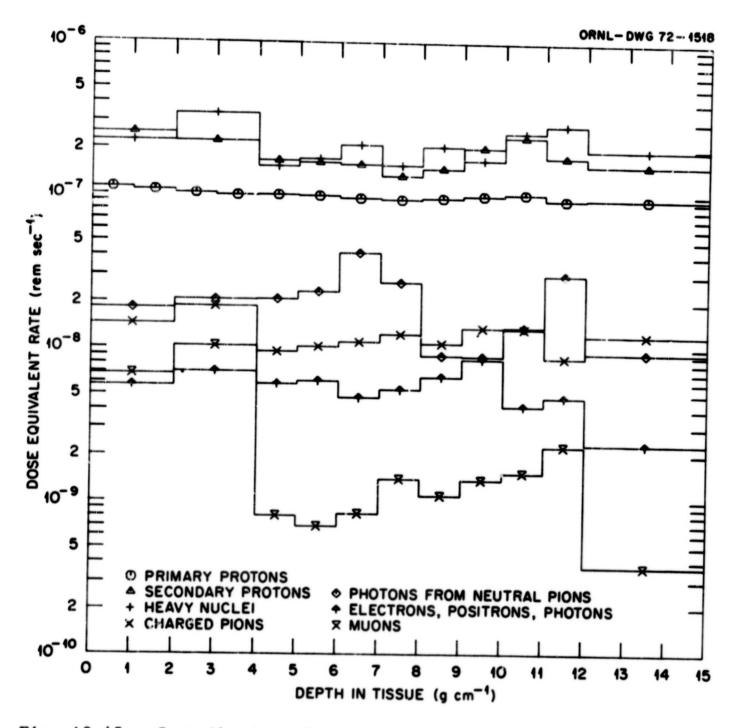


Fig. A3.45. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a galactic cosmic-ray solar-minimum proton spectrum is isotropically incident on a 20-g-cm^{-2} -thick aluminum shield.

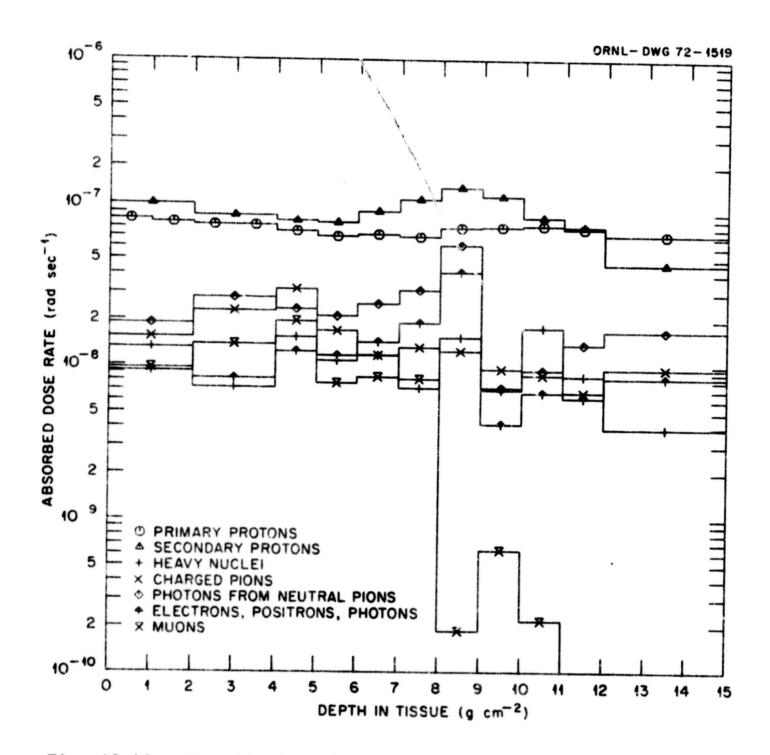


Fig. A3.46. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a galactic cosmic-ray solar-minimum proton spectrum is isotropically incident on a 35-g-cm⁻²-thick aluminum shield.

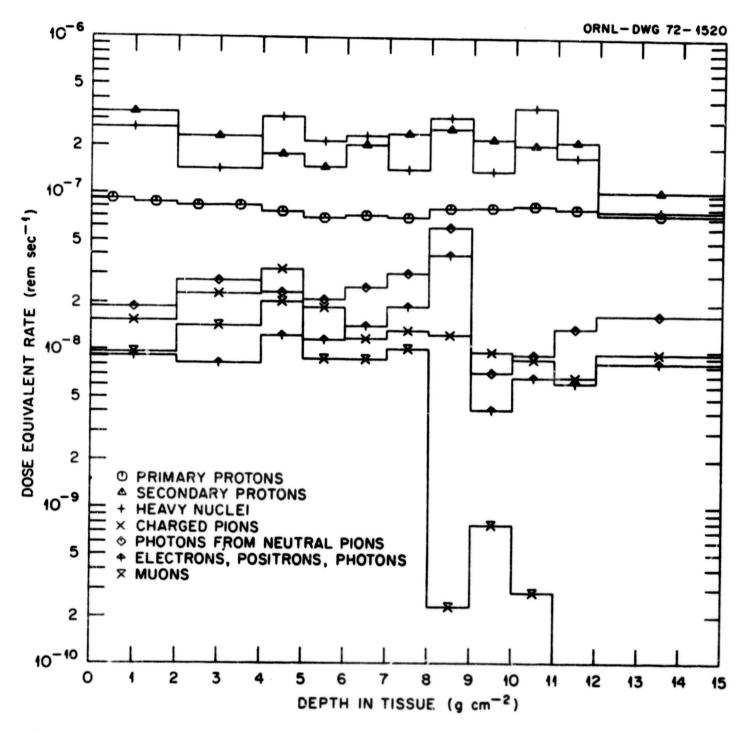


Fig. A3.47. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a galactic cosmic-ray solar-minimum proton spectrum is isotropically incident on a 35-g-cm⁻²-thick aluminum shield.

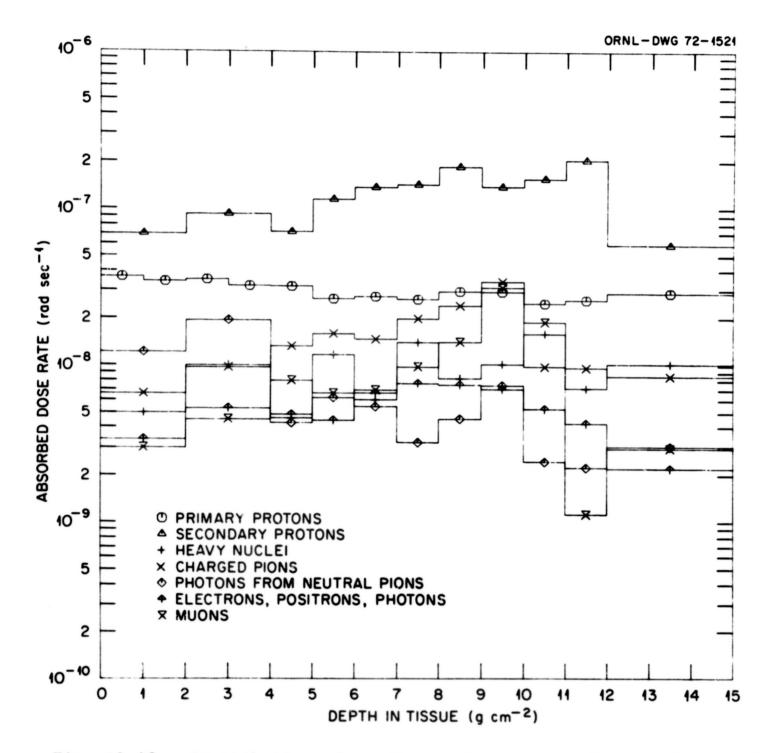


Fig. A3.48. Contributions from the various types of particles to the absorbed-dose rate as a function of depth in tissue when a galactic cosmic-ray solar-maximum proton spectrum is isotropically incident on a $35-g-cm^{-2}$ -thick aluminum shield.

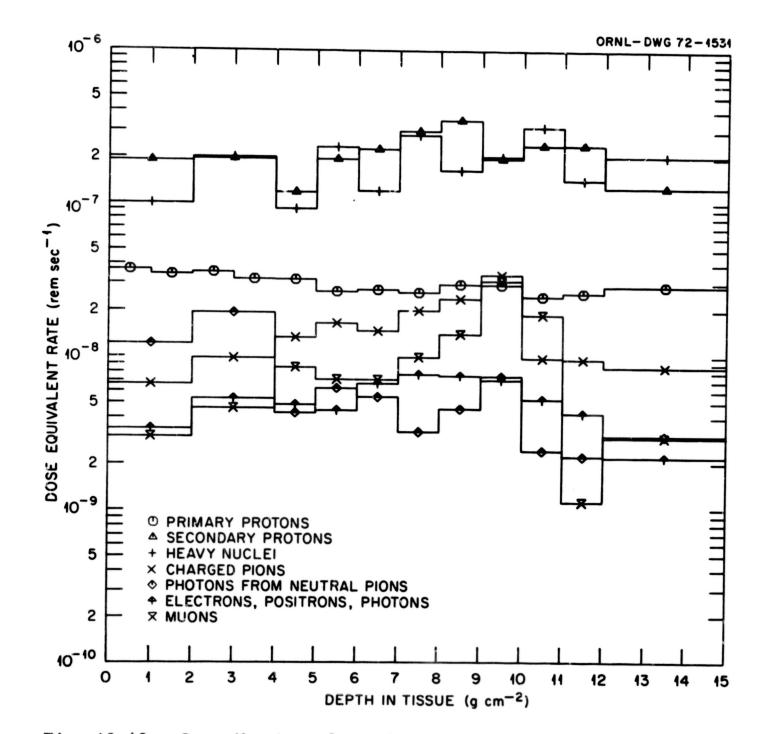


Fig. A3.49. Contributions from the various types of particles to the dose-equivalent rate as a function of depth in tissue when a galactic cosmic-ray solar-maximum proton spectrum is isotropically incident on a 35-g-cm⁻²-thick aluminum shield.

Appendix 4

SHIELDING AGAINST GALACTIC COSMIC-RAY ALPHA PARTICLES AND HEAVIER NUCLEI

In Chapter 7 results that include the production and transport of nuclear-reaction products for the case of incident galactic cosmic-ray protons were presented. Similar calculations for incident galactic cosmic-ray alpha particles and heavier nuclei cannot be carried out because the necessary differential particle-production data from the nuclear collisions of these particles are not available. Estimates of the absorbed-dose rate and dose-equivalent rate produced by these heavier cosmic-ray nuclei are presented in this appendix. These estimates were obtained by neglecting the contributions of all nuclear-reaction products, and therefore they must be considered to be very approximate. Results for incident galactic cosmic-ray protons are also presented for comparative purposes. Calculated data similar to those presented here were previously given by Curtis and Wilkinson¹¹⁸ and by Burrell and Wright.¹¹⁹

A4.1 METHOD OF CALCULATION

The geometry considered here is that shown in Fig. 3.1. All of the calculated results have been obtained by making suitable modifications in the code TRAPP. 103 The transport equations, which apply to incident galactic cosmic-ray heavy nuclei when nuclear-reaction products are neglected, are

^{118.} S. B. Curtis and M. C. Wilkinson, "Study of Radiation Hazards to Man on Extended Missions," National Aeronautics and Space Administration Report NASA CR-1037, 1968.

^{119.} M. O. Burrell and J. J. Wright, "The Estimation of Galactic Cosmic Ray Penetration and Dose Rates," George C. Marshall Space Flight Center Report NASA TN D-6600, 1972.

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the same as those discussed in Section 3.1 and included in TRAPP. Therefore, it was necessary to modify only the physical data in TRAPP, i.e., stopping powers, collision cross sections, etc., to obtain the results presented in this appendix.

For incident protons and alpha particles with energy < 3 GeV, the stopping powers and nuclear-collision cross sections used are those given in Sections 4.1, 4.2, 4.5, and 4.6. Above 3 GeV, the proton stopping powers were taken from the work of Hill et al. 80 and at all energies above 8 MeV, the alpha-particle stopping powers were obtained using the scaling law discussed in Section 4.2. At energies above 3 GeV, the proton and alpha-particle nuclear-collision cross sections were assumed to be constant and to be equal to their value at 3 GeV.

The stopping powers for ions heavier than alpha particles were obtained using a code written by Armstrong and Chandler.* This code calculates the proton stopping power from the Bethe-Bloch formula⁶³ and utilizes a scaling law similar to that described in Section 4.2 to obtain the stopping powers for all heavy (A > 1) ions. In the low-energy region where the ions cannot be assumed to be fully ionized, the code of Armstrong and Chandler utilizes the effective charge formulation of Bichsel.¹²⁰

The nuclear-collision cross sections for the collision of nuclei heavier than alpha particles with nuclei other than hydrogen were obtained from the

^{*}Thanks are due to T. W. Armstrong and K. C. Chandler of the Oak Ridge National Laboratory for making this code available to us prior to its publication.

^{120.} H. Bichsel, "Passage of Charged Particles Through Matter," Chapter 8c in American Institute of Physics Handbook, Second Edition, McGraw Hill, New York, 1963.

geometric expression*

$$\sigma_{A,A_{I}} = \pi r_{o}^{2} (A^{1/3} + A_{I}^{1/3})^{2}$$
, (A4.1)

where

A,A_I = the atomic weight of the target nucleus and the incident nucleus, respectively,

$$r_0 = 1.17 \times 10^{-13}$$
 cm.

The cross sections for the nuclear collisions of heavy nuclei with hydrogen were taken to be independent of energy and were assumed to be equal to the values given by Bertini 85 for 3-GeV proton-nucleus collisions. It is to be understood that the cross-section data used here are not well established and must be considered to be very approximate.

The absorbed-dose-rate and dose-equivalent-rate calculations were carried out in the manner described in Section 3.3. In particular, the quality factor as a function of linear energy transfer was taken to be that shown in Fig. 4.12.

^{*}See the review article by Webber in Ref. 8.

A4.2 RESULTS AND DISCUSSION

Calculations have been carried out for each of the nuclear species* shown in Table 2.5 incident on aluminum shields of thicknesses of 2 to 100 g cm $^{-2}$. For all shield thicknesses considered, results have been obtained with $r_T = 15$ g cm $^{-2}$ and $r_T = 0$ and with the attenuation due to nuclear collisions both included and neglected. In the case of protons and alpha particles, the solar-minimum spectra shown in Fig. 2.20 were used. In the case of heavier nuclei, the incident spectra were obtained from the solar-minimum alpha-particle spectrum given in Fig. 2.20 in the manner described in Section 2.3. The total number of incident particles (protons, alpha particles, and heavy nuclei) with energy > 30 MeV per nucleon is 3.81 particles cm $^{-2}$ sec.

In Fig. A4.1 the total absorbed-dose rate, i.e., the sum of the absorbed-dose rates from all incident-particle species, as well as the absorbed-dose rate from each incident-particle species, is shown as a function of shield thickness for the case of $r_T = 15 \text{ g cm}^{-2}$. The solid curves give the results when the attenuation due to nuclear collisions is neglected and the dashed curves give the results when the attenuation due to nuclear collisions is included. In Fig. A4.2, the total dose-equivalent rate and the dose-equivalent rate due to each of the incident-particle species are shown as a function of shield thickness for $r_T = 15 \text{ g cm}^{-2}$. In Figs. A4.3 and A4.4, similar results are given for $r_T = 0$. Numerical values for a few shield thicknesses from the curves in Figs. A4.1 to A4.4 are given in Tables A4.1 to A4.4, respectively. The most significant results to be noted from the figures is the very slow

^{*}In those cases where a single abundance is given in Table 2.5 for a group of nuclei, it has been assumed that the group may be characterized by a single atomic weight and atomic charge. The Li-B group was given Z = 4, A = 9; the P-Sc group was given Z = 18, A = 37; and the Ti-Ni group was given Z = 25, A = 54.

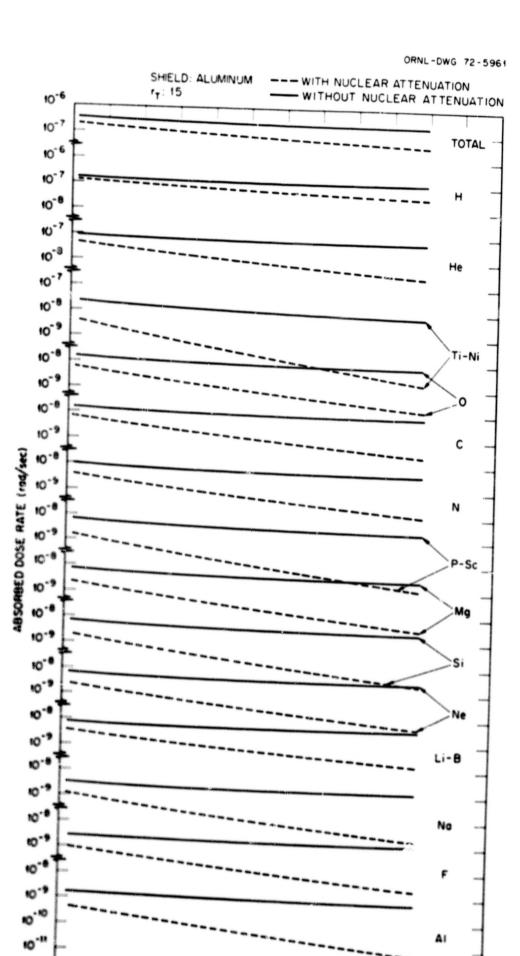


Fig. A4.1. Absorbed-dose rate of the individual galactic cosmic-ray ion species vs spherical-shell-shield thickness.

SHIELD THICKNESS (g/cm²)

10.15

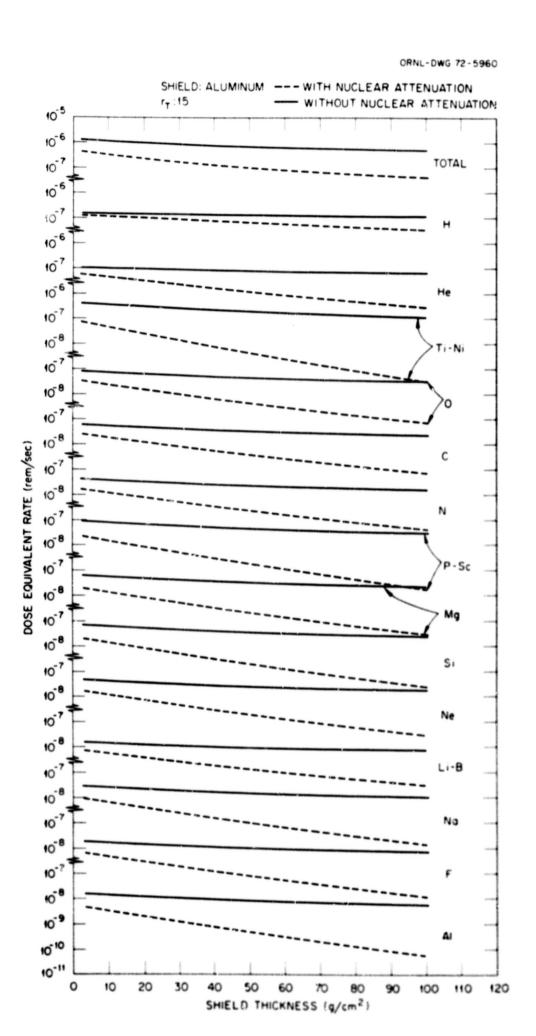


Fig. A4.2. Dose-equivalent rate of the individual galactic cosmic-ray ion species vs spherical-shell-shield thickness.

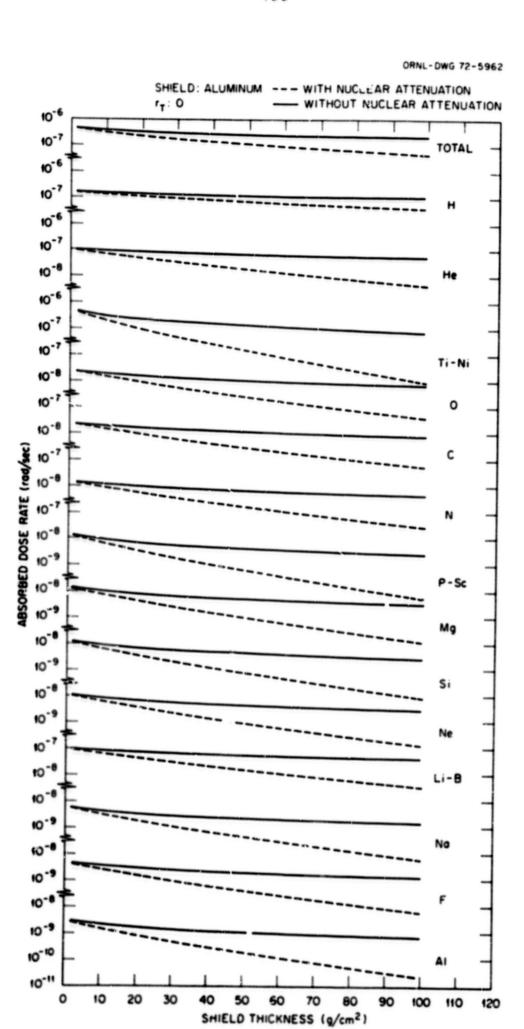


Fig. A4.3. Absorbed-dose rate of the individual galactic cosmic-ray ion species vs spherical-shell-shield thickness.

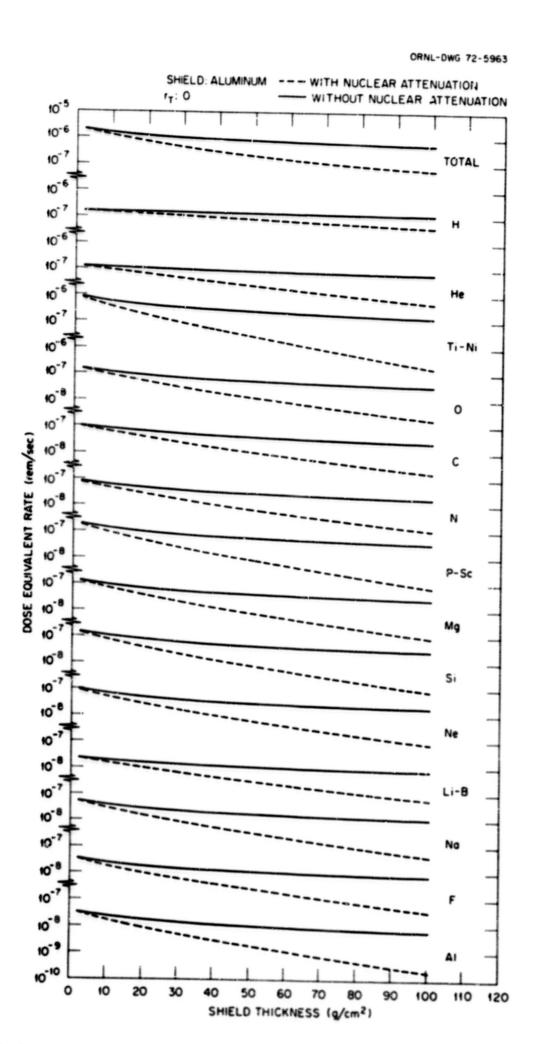


Fig. A4.4. Dose-equivalent rate of the individual galactic cosmic-ray ion species vs spherical-shell-shield thickness.

TABLE A4.1 CONTRIBUTION OF INDIVIDUAL GALACTIC COSMIC-RAY ION SPECIES TO TOTAL ANSORRED-DOSE RATE

Shield " Aluminum rr 15 g cm-2

					,		AB.	orbed-Bose Rate (rad	iec 1) and Relative A	bsorbed-Dose Rate Duc	To Incident ion Sereis	***			
44th 44th 44th 44th 44th 44th 45			.8				. 5.	0 g ce-7	1, . 2	5 g ca-2		2.00			
Without Michaelian Michae		Withou	*		With		1	Sich			. S.			S - 100 8 cm	2
10° (1.241) 1.13 × 10° (1.253) 1.45 × 10° (1.254) 1.13 × 10° (1.254) 1.13 × 10° (1.254) 1.13 × 10° (1.254) 1.13 × 10° (1.254) 1.13 × 10° (1.255) 1	E148681	Attenue	100		ctesnation	6	Attenuation	Attenuation	Attenuation	Attenuation	Without	With	Without		With
10° (1323) 1.38 * 10° (1223) 1.38 * 10° (1234) 1		1.46 * 10	(.441)		_		1.42 - 10-7 (.458)		1.15 . 10-7 / 4001	1	:		Attenuetio		tensation
10° (1031) 3.33 × 10° (1031) 6.52 × 10° (1031) 5.35 × 10° (1031) 5.36 × 10° (1131) 5.35 × 10° (1032) 5.35 × 10° (1031) 5		8.34 × 10			_		7.87 * 10-6 (.254)	-	7.18 - 10-8 (256)			6.16 × 10-8			
10°° (1045) 6.46 × 10°° (1039) 1.35 × 10°° (10°° (1046) 4.72 × 10°° (1099) 1.26 × 10°° (1099) 1.35 × 10°° (10°° (1099) 1.35 × 10°° (1099) 1.36 × 10°° (1099) 1.35 × 10°° (10°° (1099) 1.35 × 10°° (1099) 1.	-1	.04 × 10		-	_	-	6.52 - 10-9 (.021)	_				9.94 * 10-9			
10°° (.087) 3.42 × 10°° (.018) 7.95 × 10°° (.018) 7	v	1.49 × 10			-		1.35 - 10-6 (.044)					7.26 × 10-10			-
10°° (.043) 5.73 × 10°° (.030) 1.33 × 10°° (.043) 4.07 × 10°° (.044) 2.22 × 10°° (.049) 2.22 × 10°° (.031) 2.53 × 10°° (.032) 2.22 × 10°° (.032) 2.22 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.23 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2.24 × 10°° (.033) 2	×	8.84 . 10			_							1.13 * 10-9			16-10 (.006)
10°° (.008) 9.63 × 10°° (.008) 6.72 × 10°° (.008) 6.72 × 10°° (.004) 2.01 × 10°° (.007) 3.57 × 10°° (.003) 1.62 × 10°° (.003) 1.34 × 10°° (.004) 1.34 × 10°° (.004) 1.34 × 10°° (.004) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.003) 1.34 × 10°° (.004) 1	0	1.48 * 10					1.33 * 10-8 (.043)					5.92 × 10-10			10-19 (.003)
10°° (.019) 2.24 × 10°° (.021) 5.64 × 10°° (.018) 1.54 × 10°° (.019) 4.71 × 10°° (.001) 3.57 × 10°° (.002) 1.62 × 10°° (.002) 1.34 × 10°° (.004) 2.70 × 10°° (.004) 1.75 × 10°° (.004) 1		2.68 . 10									-	8.72 × 10-10			10-10 (.004)
10 ⁻³ (.010) 1.69 × 10 ⁻³ (.006) 2.93 × 10 ⁻³ (.009) 7.38 × 10 ⁻¹⁰ (.009) 1.52 × 10 ⁻¹⁰ (.000) 1.52 × 10 ⁻¹⁰ (.000) 1.52 × 10 ⁻¹⁰ (.001) 1.52 × 10 ⁻¹⁰ (.001) 1.52 × 10 ⁻¹⁰ (.002) 1.37 × 10 ⁻¹⁰ (.002) 1.37 × 10 ⁻¹⁰ (.004) 3.10 × 10 ⁻¹⁰ (.002) 1.13 × 10 ⁻¹⁰ (.002) 1.32 × 10 ⁻¹⁰ (.001) 3.69 × 10 ⁻¹⁰ (.002) 1.32 × 10 ⁻¹⁰ (.001) 3.69 × 10 ⁻¹⁰ (.001) 1.52 × 10 ⁻¹⁰ (.002) 1.92 × 10 ⁻¹⁰ (.001) 3.69 × 10 ⁻¹⁰ (.001) 3.69 × 10 ⁻¹⁰ (.002) 1.44 × 10 ⁻¹⁰ (.001) 1.54 × 10 ⁻¹⁰ (.002) 1.52 × 10 ⁻¹⁰ (.002) 1.53 × 10	2	6.37 × 10"					1.64 × 10"9 (.018)					1.34 × 10-10			10-11 (.0006)
10 ⁻⁹ (.021) 2.28 × 10 ⁻⁹ (.012) 6.20 × 10 ⁻⁹ (.020) 1.52 × 10 ⁻⁹ (.000) 3.12 × 10 ⁻¹⁰ (.000) 1.94 × 10 ⁻¹⁰ (.002) 1.94 × 10 ⁻¹⁰ (.000) 3.12 × 10 ⁻¹⁰ (.002) 1.95 × 10 ⁻⁹ (.001) 2.62 × 10 ⁻¹⁰ (.002) 1.92 × 10 ⁻⁹ (.003) 2.64 × 10 ⁻¹⁰ (.004) 3.10 × 10 ⁻⁹ (.002) 1.92 × 10 ⁻⁹ (.004) 1.52 × 10 ⁻⁹ (.004) 3.10 × 10 ⁻⁹ (.005) 2.39 × 10 ⁻⁹ (.006) 4.65 × 10 ⁻⁹ (.016) 4.52 × 10 ⁻⁹ (.006) 3.60 × 10 ⁻⁹ (.008) 3.60 × 10 ⁻⁹ (.012) 3.70 × 10	No.	3.32 × 10-1		1.09						8.07 * 10 * (.007)					10-13 (.001)
10 ⁻⁹ (.005) 4.67 × 10 ⁻¹⁰ (.002) 1.37 × 10 ⁻⁹ (.004) 3.10 × 10 ⁻⁹ (.004) 1.52 × 10 ⁻¹⁰ (.004) 6.82 × 10 ⁻¹⁰ (.004) 5.69 × 10 ⁻⁹ (.018) 1.26 × 10 ⁻⁹ (.019) 1.28 × 10 ⁻⁹ (.018) 1.26 × 10 ⁻⁹ (.019) 1.26 × 10 ⁻⁹	*	7.07 * 10-1		2.26				_	(17 × 10-9 , 010)	3.76 * 10 ** (.003)		1.32 × 10-10 (.002)	•		10-11 (.5005)
10 ⁻⁹ (.020) 1.92 × 10 ⁻⁹ (.010) 5.69 × 10 ⁻⁹ (.018) 1.26 × 10 ⁻⁹ (.006) 4.65 × 10 ⁻⁹ (.017) 6.12 × 10 ⁻¹⁰ (.001) 6.82 × 10 ⁻¹⁰ (.004) 5.48 × 10 ⁻⁹ (.018) 1.26 × 10 ⁻⁹ (.006) 4.65 × 10 ⁻⁹ (.017) 6.12 × 10 ⁻¹⁰ (.005) 3.60 × 10 ⁻⁹ (.015) 1.98 × 10 ⁻⁹ (.013) 1.31 × 10 ⁻¹⁰ (.002) 2.47 × 10 ⁻⁹ (.012) 10 ⁻⁹ (.012) 1.58 × 10 ⁻⁹ (.013) 1.31 × 10 ⁻¹⁰ (.002) 2.20 × 10 ⁻⁹ (.012) 10 ⁻⁹ (.013) 1.05 × 10 ⁻⁹ (.013) 1.05	7	1.56 × 10-	(:002)						1 13 x 10-9 (006)	(900.) 01 . 90./		2.62 × 10-10 (.003)			10-11 (.001)
10 ⁻⁸ (.065) 1.58 × 10 ⁻⁹ (.008) 5.48 × 10 ⁻⁹ (.018) 1.00 × 10 ⁻⁵ (.006) 4.40 × 10 ⁻⁹ (.016) 4.52 × 10 ⁻¹⁰ (.004) 3.33 × 10 ⁻⁹ (.013) 1.31 × 10 ⁻¹⁰ (.003) 2.47 × 10 ⁻⁹ (.011) 1.54 × 10 ⁻⁹ (.018) 1.00 × 10 ⁻⁹ (.018) 1.44 × 10 ⁻⁹ (.019) 1.44 × 10 ⁻⁹ (.019) 1.05 × 10 ⁻⁹ (.013) 1.31 × 10 ⁻⁹ (.014) 1.31 × 10 ⁻⁹ (.015) 1.31 × 10 ⁻⁹	27	6.34 × 10"9	(.020)	1.92						1.52 * 10 .0 (.001)		5.04 × 10-11 (.0007)		_	
10 ⁻⁸ (.065) 4.00 × 10 ⁻⁹ (.021) 1.84 × 10 ⁻⁸ (.059) 2.39 × 10 ⁻⁹ (.015) 1.44 × 10 ⁻⁸ (.051) 9.69 × 10 ⁻¹⁰ (.004) 3.33 × 10 ⁻⁹ (.013) 1.31 × 10 ⁻¹⁰ (.002) 2.20 × 10 ⁻⁹ (.011) 10 ⁻⁷ (.305) 3.37 × 10 ⁻⁸ (.174) 8.94 × 10 ⁻⁸ (.285) 2.34 × 10 ⁻⁸ (.144) 7.42 × 10 ⁻⁸ (.264) 1.24 × 10 ⁻⁸ (.104) 5.89 × 10 ⁻⁹ (.238) 4.78 × 10 ⁻⁹ (.063) 4.21 × 10 ⁻⁹ (.204) 1.94 × 10 ⁻⁷ 11.94 × 10 ⁻⁷ 3.10 × 10 ⁻⁷ 1.62 × 10 ⁻⁷ 2.81 × 10 ⁻⁷ 1.19 × 10 ⁻⁷ 2.48 × 10 ⁻⁷ 7.63 × 10 ⁻⁸ 2.06 × 10 ⁻⁷ 2.06 × 10 ⁻⁷ 3.00 × 10 ⁻⁸ 2.06 × 10 ⁻⁷ 3.00 × 10 ⁻⁸ 3.00 × 10 ⁻⁷ 3.00 × 10 ⁻	P-Sc	6.37 × 10"9		1.58								1.98 × 10-10 (.003)			10-11 (.0007)
0 ⁻⁷ (.305) 3.37 × 10 ⁻⁸ (.174) 8.94 × 10 ⁻⁸ (.288) 2.34 × 10 ⁻⁸ (.144) 7.42 × 10 ⁻⁸ (.264) 1.24 × 10 ⁻⁸ (.104) 5.89 × 10 ⁻⁸ (.238) 4.78 × 10 ⁻⁹ (.063) 6.50 × 10 ⁻⁹ (.204) 10 ⁻⁷ 1.94 × 10 ⁻⁷ 3.10 × 10 ⁻⁷ 1.62 × 10 ⁻⁷ 2.81 × 10 ⁻⁷ 1.19 × 10 ⁻⁷ 2.48 × 10 ⁻⁷ 7.63 × 10 ⁻⁸ 2.06 × 10 ⁻⁷ 3.00 × 10 ⁻⁸ (.204) 10 ⁻⁷ 2.48 × 10 ⁻⁷ 7.63 × 10 ⁻⁸ 2.06 × 10 ⁻⁷ 3.00 × 10	T1-N1	2.16 × 10"	(.065)	4.00						4.52 * 10 10 (.004)		1.31 × 10-10 (.002)			10-11 (.0004)
0 ⁻⁷ (.305) 3.37 × 10 ⁻⁸ (.174) 8.94 × 10 ⁻⁸ (.288) 2.34 × 10 ⁻⁸ (.144) 7.42 × 10 ⁻⁸ (.264) 1.24 × 10 ⁻⁹ (.104) 5.89 × 10 ⁻⁸ (.238) 4.78 × 10 ⁻⁹ (.063) 4.21 × 10 ⁻⁹ (.204) 0 ⁻⁷ 1.94 × 10 ⁻⁷ 3.10 × 10 ⁻⁷ 1.62 × 10 ⁻⁷ 2.81 × 10 ⁻⁷ 1.19 × 10 ⁻⁷ 2.48 × 10 ⁻⁷ 7.63 × 10 ⁻⁹ 2.06 × 10 ⁻⁷ dent ion species by the total absorbed-dose rate.	ion of al									(900) 01 : 69.6		2.36 × 10 ⁻¹⁰ (.603)			10-11 (.0004)
0 ⁻⁷ 1.94 × 10 ⁻⁷ 3.10 × 10 ⁻⁷ 1.62 × 10 ⁻⁸ (.144) 7.42 × 10 ⁻⁸ (.264) 1.24 × 10 ⁻⁸ (.104) 5.89 × 10 ⁻⁹ (.238) 4.78 × 10 ⁻⁹ (.063) 4.21 × 10 ⁻⁹ (.204) arentheses are the relative absorbed-dose rates and were obtained by dividing the absorbed-dose rate. 2.48 × 10 ⁻⁷ 7.63 × 10 ⁻⁹ 2.06 × 10 ⁻⁷ 4.20 × 10 ⁻⁷ 4.20 × 10 ⁻⁹ 4.21 × 10 ⁻⁹ 4.21 × 10 ⁻⁹ 4.20 × 10 ⁻⁹ 4.21 × 10 ⁻⁹ 4.21 × 10 ⁻⁹ 4.20	L to Mi	1.02 × 10-7	(300)												
0^{-7} 1.94 × 10^{-7} 3.10 × 10^{-7} 1.62 × 10^{-7} 2.81 × 10^{-7} 1.19 × 10^{-7} 2.48 × 10^{-7} 7.63 × 10^{-9} 2.06 × 10^{-7} dent for species by the total absorbed-dose rate.	otal ab-														0-10 (.024)
0^{-7} 1.94 × 10^{-7} 3.10 × 10^{-7} 1.62 × 10^{-7} 2.81 × 10^{-7} 1.19 × 10^{-7} 2.48 × 10^{-7} 7.63 × 10^{-9} 2.06 × 10^{-7} dent for species by the total absorbed-dose rate.	orbed-dos														
dent ion species by the total absorbed-dose rate.	(t_3)	3.31 × 10-7		1.94	10-7	•		1.62 * 10-7			,				
dent ion special by the total absorbed-dose rate.	The numb	ers in pares	theses	are the	relative	absorbe	-dose rates and un	the other frank has district	77 - 16.	1.19 × 10	2.48 × 10-7	7.63 × 10 ⁻⁸	2.06 × 10-7	3.54 × 1	9-0
	due to e	ach incident	ton sp	scies b	y the tota	il absor	ed-dose rate.	e optained by dividu	ig the absorbed-dose	rate					

TABLE A4.2

CONTRIBUTION OF INDIVIDUAL GALACTIC COSMIC-RAY ION SPECIES TO TOTAL DOSE-EQUIVALENT RATE

Shield = Aluminum r_T = 15 g cm⁻²

Dose-Equivalent Rate (rem sec-1) and Relative Dose-Equivalent Rate Due To Incident Ion Species*

	r _s - 2	8 cm ⁻²	r _S - 10	g cm ⁻²	r _s - 25	g cm ⁻²	r _S = 50	g cm ⁻²	r _s - 10	0 g cm ⁻²
Element	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation
	1.50 × 10 ⁻⁷ (.126)	1.20 × 10 ⁻⁷ (.280)	1.45 × 10 ⁻⁷ (.140)	1.08 × 10 ⁻⁷ (.344)	1.38 × 10 ⁻⁷ (.162)	8.78 × 10 ⁻⁸ (.459)	1.27 × 10 ⁻⁷ (.190)	6.29 × 10 ⁻⁸ (.627)	1.12 × 10 ⁻⁷ (.233)	3.28 × 10 ⁻⁸ (.839)
He	1.04 × 10 ⁻⁷ (.088)	5.34 × 10 ⁻⁸ (.124)	9.62 × 10 ⁻⁸ (.093)	4.06 × 10 ⁻⁸ (.130)	8.58 × 10 ⁻⁸ (.101)	2.48 × 10 ⁻⁸ (.130)		1.15 × 10 ⁻⁸ (.114)	6.07×10^{-8} (.126)	2.66 × 10 ⁻⁹ (.058)
L1-B	1.53 × 10 ⁻⁸ (.013)	7.28 × 10 ⁻⁹ (.017)	1.35×10^{-8} (.013)	5.29 × 10 ⁻⁹ (.017)	1.13 × 10 ⁻⁸ (.013)	3.05 × 10 ⁻⁹ (.016)	9.01 × 10 ⁻⁹ (.013)	1.31 × 10 ⁻⁹ (.013)	6.62×10^{-9} (.014)	2.79 × 10 ⁻¹⁰ (.007)
C	5.77 × 10 ⁻⁸ (.049)	2.50×10^{-8} (.058)	5.00×10^{-8} (.048)	1.75 × 10 ⁻⁸ (.056)	4.08×10^{-8} (.048)	9.57 × 10 ⁻⁹ (.050)	3.18×10^{-8} (.047)	3.81 × 10 ⁻⁹ (.038)	2.26×10^{-8} (.047)	7.12 × 10 ⁻¹⁰ (.018)
×	4.15 × 10 ⁻⁸ (.035)	1.70 × 10 ⁻⁸ (.040)	3.59 × 10 ⁻⁸ (.035)	1.17 × 10 ⁻⁸ (.040)		6.25 × 10 ⁻⁹ (.033)	2.24 × 10 ⁻⁸ (.034)	2.40 × 10 ⁻⁹ (.024)		4.17×10^{-10} (.011)
0	8.27 × 10 ⁻⁸ (.070)	3.20 × 10 ⁻⁸ (.074)	7.12 × 10 ⁻⁸ (.069)	2.19 × 10 ⁻⁸ (.070)	5.73 × 10 ⁻⁸ (.067)	1.14 × 10 ⁻⁸ (.059)	4.41 × 10 ⁻⁸ (.066)	4.23 × 10 ⁻⁹ (.042)	3.08 × 10 ⁻⁸ (.064)	6.88 × 10 ⁻¹⁰ (.018)
7	1.72 × 10 ⁻⁸ (.014)	6.20 × 10 ⁻⁹ (.014)	1.48×10^{-8} (.014)	4.18 × 10 ⁻⁹ (.013)	1.19 × 10 ⁻⁸ (.014)	2.12 × 10 ⁻⁹ (.011)	9.15 × 10 ⁻⁹ (.014)	7.54 × 10 ⁻¹⁰ (.008)	6.37×10^{-9} (.013)	$1.13 \times 10^{-10} (.003)$
Ne	4.60 × 10 ⁻⁸ (.039)	1.62 × 10 ⁻⁸ (.038)	$3.92 \times 10^{-8} (.038)$	1.08 × 10 ⁻⁸ (.034)	3.13 × 10 ⁻⁸ (.037)	5.36 × 10 ⁻⁹ (.028)	2.38 × 10 ⁻⁸ (.036)	1.87 × 10 ⁻⁹ (.019)	$1.63 \times 10^{-8} (.034)$	2.68 × 10 ⁻¹⁰ (.007)
Na	2.70 × 10 ⁻⁸ (.023)	8.83 × 10 ⁻⁹ (.021)	$2.30 \times 10^{-8} (.022)$	5.80 × 10 ⁻⁹ (.019)	1.83 × 10 ⁻⁸ (.022)	2.83 × 10 ⁻⁹ (.015)	1.39 × 10 ⁻⁸ (.021)	9.50×10^{-10} (.009)		1.26×10^{-10} (.003)
Ne	6.37 × 10 ⁻⁸ (.054)	2.04 × 10 ⁻⁸ (.048)	$5.41 \times 10^{-8} (.052)$	1.33×10^{-8} (.042)	4.29 × 10 ⁻⁸ (.050)	6.41 × 10 ⁻⁹ (.033)	3.24 × 10 ⁻⁸ (.048)	2.11 × 10 ⁻⁹ (.021)		2.71 × 10 ⁻¹⁰ (.007)
A1	1.56 × 10 ⁻⁸ (.013)	4.66 × 10 ⁻⁹ (.011)	1.32×10^{-8} (.013)	3.01 × 10 ⁻⁹ (.010)	1.05 × 10 ⁻⁸ (.012)	1.42 × 10 ⁻⁹ (.007)				5.44 × 10 ⁻¹¹ (.001)
S1	$7.12 \times 10^{-8} (.060)$	2.09 × 10 ⁻⁸ (.049)		1.34 × 10 ⁻⁸ (.039)		6.27 × 10 ⁻⁹ (.033)		1.97 × 10 ⁻⁹ (.020)	$2.37 \times 10^{-8} (.050)$	2.28 × 10 ⁻¹⁰ (.006)
P-Sc	9.12 × 10 ⁻⁸ (.077)	$2.26 \times 10^{-8} (.053)$		1.41 × 10 ⁻⁸ (.045)		6.23 × 10 ⁻⁹ (.033)				1.69 × 10 ⁻¹⁰ (.004)
T1-N1	$4.02 \times 10^{-7} (.339)$	7.44×10^{-8} (.173)	3.39×10^{-7} (.328)	4.42 × 10 ⁻⁸ (.141)	2.65 × 10 ⁻⁷ (.311)	1.78 × 10 ⁻⁸ (.093)	1.93 × 10 ⁻⁷ (.288)	4.32 × 10 ⁻⁹ (.043)	1.18×10^{-7} (.247)	2.94 × 10 ⁻¹⁰ (.007)
Contribu- tion of a elements Li to Ni	11 from	2.55 × 10 ⁻⁷ (.594)	7.91 × 10 ⁻⁷ (.768)	1.65 × 10 ⁻⁷ (.525)	6.27 × 10 ⁻⁷ (.737)	7.87 × 10 ⁻⁸ (.412)	4.68 × 10 ⁻⁷ (.698)	2.59 × 10 ⁻⁸ (.259)	3.06 × 10 ⁻⁷ (.639)	3.62 × 10 ⁻⁹ (.092)
	1.18 × 10 ⁻⁶	4.29 × 10 ⁻⁷	1.03 × 10 ⁻⁷	3.14 × 10 ⁻⁷	8.51 × 10 ⁻⁷	1.91 × 10 ⁻⁷	6.70 × 10 ⁻⁷	1.00 × 10 ⁻⁷	4.79 × 10 ⁻⁷	3.91 × 10 ⁻⁸

The numbers in parentheses are the relative dose-equivalent rates and were obtained by dividing the dose-equivalent rate due to each incident ion species by the total dose-equivalent rate.

TABLE A4.3

CONTRIBUTION OF INDIVIDUAL GALACTIC COSMIC-RAY ION SPECIES TO TOTAL ABSORBED-DOSE RATE

Shield = Aluminum r_T = 0 g cm⁻²

Absorbed-Dose Rate (rad sec-1) and Relative Absorbed-Dose Rate Due To Incident Ion Species

	r _e = 2	e cm-2	1	orbed-bose Rate (rad s	sec ') and Relative A	and Relative Absorbed-Dose Rate Due To Incident Ion Species				
	Without) g cm ⁻²	r _S =	25 g cm ⁻²	r _S = 5	0 g cm ⁻²	r _e = 1	00 g cm ⁻²
Element	Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without	With
н	1.54×10^{-7} (.360)	1.51×10^{-7} (.366)	1 53 × 10-7 (400)	1.38 × 10 ⁻⁷ (.457)					Attenuation	Attenuation
He	9.78 × 10 ⁻⁸ (.229)			7.16×10^{-8} (.236)	1.44 × 10 ⁻⁷ (.450)		1.33×10^{-7} (.486)	8.00 × 10 ⁻⁸ (.701)	1.15 × 10 ⁻⁷ (.525)	4.15 × 10 ⁻⁸ (.859)
L1-B	9.19 × 10 ⁻⁹ (.022)				8.14 × 10 ⁻⁸ (.253)		7.00×10^{-8} (.256)	1.99 × 10 ⁻⁸ (.176)		4.59 × 10 ⁻⁹ (.095)
C			$8.17 \times 10^{-9} (.022)$	6.39×10^{-9} (.021)	6.82×10^{-9} (.021)	3.68×10^{-9} (.019)	5.61 × 10 ⁻⁹ (.021)	1.63 × 10 ⁻⁹ (.014)	4 25 × 10 ⁻⁹ (200)	4.59 ~ 10 ~ (.095)
·	$2.21 \times 10^{-8} (.052)$		$1.81 \times 10^{-8} (.048)$	1.39×10^{-8} (.046)		7.32×10^{-9} (.037)	1 11 × 10-8 (0(1)	2.03 - 10 (.014)	4.33 * 10 * (.020)	3.67 × 10 10 (.007)
N	1.36×10^{-8} (.032)	1.29×10^{-8} (.031)		8.24×10^{-9} (.027)		4.19 × 10 ⁻⁹ (.021)	1.11 ^ 10 - (.041)	2.92 × 10 ⁻⁹ (.026)	8.06 × 10 ⁻⁹ (.037)	5.56×10^{-10} (.011)
0	2.36 × 10 ⁻⁸ (.055)	2.23×10^{-8} (.054)	$1.85 \times 10^{-8} (.049)$				$6.46 \times 10^{-9} (.024)$	1.60 × 10 ⁻⁹ (.014)	4.61×10^{-9} (.021)	2.81×10^{-10} (.006)
F	4.34 × 10 ⁻⁹ (.010)					6.82×10^{-9} (.034)	$1.07 \times 10^{-8} (.039)$	2.49 × 10 ⁻⁹ (.022)	7.50×10^{-9} (.034)	4.08 × 10-10 (008)
Ne				2.47 × 10 ⁻⁹ (.008)	2.54 × 10 ⁻⁹ (.008)	1.18×10^{-9} (.006)	1.90×10^{-9} (.007)	4.12 × 10 ⁻¹⁰ (.004)	1 33 x 10 ⁻⁹ (006)	6.17 × 10-11 (000)
	1.08 × 10 ⁻⁸ (.025)		8.10×10^{-9} (.022)		6.02×10^{-9} (.019)	2.76 × 10 ⁻⁹ (.014)	4.46 x 10 ⁻⁹ (016)	0.36 × 10-10 (000)	1.55 ~ 10 (.006)	6.17 × 10 ·· (.001)
Na	3.69 × 10 ⁻⁹ (.013)		4.23×10^{-9} (.011)	3.06×10^{-9} (.010)	3.13 × 10 ⁻⁹ (.010)		2.20 10 (.010)	9.36 × 10 ⁻¹⁰ (.008)	3.04 × 10 3 (.014)	$1.34 \times 10^{-10} \text{ (.003)}$
Mg	$1.26 \times 10^{-8} (.029)$	1.18×10^{-8} (.028)	9.13×10^{-9} (.024)				2.30 × 10 ⁻³ (.008)	$4.50 \times 10^{-10} (.004)$	1.56×10^{-9} (.007)	5.96×10^{-11} (.001)
A1	2.81 × 10 ⁻⁹ (.007)		2.03 × 10 ⁻⁹ (.005)			2.90 × 10 ⁻⁹ (.015)	4.82×10^{-9} (.018)	9.22 × 10 ⁻¹⁰ (.008)	3.20×10^{-9} (.015)	1.17×10^{-10} (.002)
	1.21 × 10 ⁻⁸ (.028)					6.21×10^{-10} (.003)	1.06×10^{-9} (.004)	1.90×10^{-10} (.002)	6.99 x 10 ⁻¹⁰ (003)	2 22 × 10-11 (0005)
			8.58×10^{-9} (.023)		6.12×10^{-9} (.019)	2.56×10^{-9} (.013)	4.37 × 10 ⁻⁹ (016)	7.65 × 10 ⁻¹⁰ (.007)	0.00 10 (.003)	2.23 × 10 · · (.0005)
	1.26×10^{-8} (.029)		8.54×10^{-9} (.023)	5.83×10^{-9} (.019)		2.27 × 10 ⁻⁹ (.011)	4.37 - 10 (.010)	7.65 × 10 · · (.007)	2.82 × 10 ° (.013)	$8.66 \times 10^{-11} (.002)$
T1-N1	$4.63 \times 10^{-8} (.108)$	4.24×10^{-8} (.103)	2.99 × 10 ⁻⁸ (.080)				4.11 × 10 5 (.015)	6.04×10^{-10} (.005)	2.55×10^{-9} (.012)	5.51×10^{-11} (.001)
Contribu-			(1000)	1.72 ~ 10 (.004)	1.99 × 10 ° (.062)	6.65 × 10 ⁻⁹ (.034)	$1.33 \times 10^{-8} (.049)$	1.48 × 10 ⁻⁹ (.013)	7.76×10^{-9} (.035)	$9.57 \times 10^{-11} (.002)$
tion of a										(1302)
elements i										
Li to Ni	1.74×10^{-7} (.408)	$1.69 \times 10^{-7} (.409)$	1.30×10^{-7} (.347)	9.29 × 10 ⁻⁸ (.307)	9.53 x 10 ⁻⁸ (207)	4 22 × 10-8 (214)	7 00 10=8 (05=)			
Total ab-				,,,,,,	3.33 × 10 · (.297)	4.23 × 10 ⁻⁸ (.214)	7.02 × 10 ⁻⁶ (.257)	1.44×10^{-8} (.126)	4.75×10^{-8} (.217)	2.24×10^{-9} (.046)
sorbed-dos	se									
rate (rad	4.26 × 10 ⁻⁷									
		4.13 × 10 ⁻⁷		3.02×10^{-7}	3.21 × 10 ⁻⁷	1.98×10^{-7}	2.73 × 10 ⁻⁷	1.14 × 10 ⁻⁷	2.19 × 10 ⁻⁷	
"The number	ers in parentheses ar	e the relative absorb	ed-dose rates and was	e obtained by dividia				1114 ~ 10	2.19 × 10 '	4.83 × 10 ⁻⁸

The numbers in parentheses are the relative absorbed-dose rates and were obtained by dividing the absorbed-dose rate due to each incident ion species by the total absorbed-dose rate.

TABLE A4.4

CONTRIBUTION OF INDIVIDUAL GALACTIC COSMIC-RAY ION SPECIES TO TOTAL DOSE-EQUIVALENT RATE

Shield - Aluminum r_T - 0 g cm⁻²

Dose-Equivalent Rate (rem \sec^{-1}) and Relative Dose-Equivalent Rate Due To Incident Ion Species $^{f a}$

	r _S • 2	8 cm_5	r _S - 10) g cm ⁻²	2 _S - 2	5 g cm ⁻²	r _s - 5	0 g cm ⁻²	r _s - 10	00 g cm ^{−2}
Element	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without Attenuation	With Attenuation	Without	With Attenuation
H	1.57 × 10 ⁻⁷ (.070)	1.53 × 10 ⁻⁷ (.073)	1.58 × 10 ⁻⁷ (.101)	1.42 × 10 ⁻⁷ (.126)	1.49 × 10 ⁻⁷ (.133)	1.15 × 10 ⁻⁷ (.223)	1.36 × 10 ⁻⁷ (.159)	8.22 × 10 ⁻⁸ (.403)	1.18 x 10 ⁻⁷ (218)	4.25 × 10 ⁻⁸ (.717)
He	$1.25 \times 10^{-7} (.056)$	1.19 × 10 ⁻⁷ (.057)	1.18 × 10 ⁻⁷ (.075)	9.21 × 10 ⁻⁸ (.082)		5.43 × 10 ⁻⁸ (.105)		2.39 × 10 ⁻⁸ (.117)		5.30 × 10 ⁻⁹ (.089)
L1-B	2.37 × 10 ⁻⁸ (.011)	2.26 × 10 ⁻⁸ (.011)	2.02 × 10 ⁻⁸ (.013)	1.58×10^{-8} (.014)		8.08 × 10 ⁻⁹ (.016)		3.21×10^{-9} (.016)		$6.39 \times 10^{-10} \text{ (.011)}$
С	1.05×10^{-7} (.047)	9.97 × 10 ⁻⁸ (.048)	7.82 × 10 ⁻⁸ (.050)	5.99 × 10 ⁻⁸ (.053)	5.50 × 10 ⁻⁸ (.049)	2.82 × 10 ⁻⁸ (.055)		1.93 × 10 ⁻⁸ (.950)		1.78 × 10 ⁻⁹ (.030)
N		$7.42 \times 10^{-8} (.035)$	5.68 × 10 ⁻⁸ (.036)	4.30×10^{-8} (.038)	$3.94 \times 10^{-8} (.035)$	1.96 * 10-8 (.038)		6.83 × 10 ⁻⁹ (.034)		1.10 × 10 ⁻⁹ (.019)
0		$1.52 \times 10^{-7} (.073)$	1.13×10^{-7} (.072)	$8.47 \times 10^{-8} (.075)$	$7.81 \times 10^{-6} (.670)$	3.78 × 10 ⁻⁸ (.073)	5.43 × 10 ⁻⁸ (.067)	1.27×10^{-8} (.062)		1.92 × 10 ⁻⁹ (.032)
P		3.20×10^{-8} (.015)	2.37 × 10 ⁻⁸ (.015)	1.74 × 10 ⁻⁸ (.015)	$1.62 \times 10^{-8} (.015)$	7.54 × 10 ⁻⁹ (.015)	1.12 × 10 ⁻⁸ (.014)	2.43×10^{-9} (.012)		$3.38 \times 10^{-10} (.006)$
Ne		8.96 × 10 ⁻⁸ (.043)	$6.40 \times 10^{-6} (.041)$	4.68 × 10 ⁻⁸ (.042)	$4.31 \times 10^{-8} (.039)$	$1.98 \times 10^{-8} (.038)$	2.94 × 10 ⁻⁶ (.037)	$6.19 \times 10^{-9} (.030)$		8.26 × 10 ⁻¹⁰ (.014)
Na		$5.25 \times 10^{-8} \ (.025)$	3.74 × 10 ⁻⁸ (.024)		$2.52 \times 10^{-8} (.023)$	1.12 × 10 ⁻⁸ (.022)	1.72×10^{-8} (.021)	3.37×10^{-9} (.017)		4.16×10^{-10} (.007)
Mg		1.27×10^{-7} (.061)		$6.39 \times 10^{-8} (.057)$	$5.93 \times 10^{-8} (.053)$	2.59 × 10 ⁻⁸ (.050)	4.02 × 10 ⁻⁸ (.050)	$7.68 \times 10^{-9} (.038)$		9.17×10^{-10} (.015)
Al		$3.10 \times 10^{-8} \text{ (.015)}$		1.54 × 10 ⁻⁸ (.014)		$6.14 \times 10^{-9} (.012)$	9.84 × 10 ⁻⁹ (.012)	$1.76 \times 10^{-9} \ (.009)$		1.96 × 10 ⁻¹⁰ (.003)
S1		$1.44 \times 10^{-7} (.069)$	$9.95 \times 10^{-8} (.063)$			2.76 × 10 ⁻⁸ (.053)	$4.45 \times 10^{-8} (.055)$	7.80 > 10 ⁻⁹ (.038)		8.42 × 10 ⁻¹⁰ (.014)
P-Sc		1.85 × 10 ⁻⁷ (.088)	1.27×10^{-7} (.081)			$3.23 \times 10^{-8} \ (.063)$	5.64 × 10 ⁻⁸ (.070)	$8.30 \times 10^{-9} (.041)$		7.37 × 10 ⁻¹⁰ (.012)
T1-N1	8.86 × 10 ⁻⁷ (.394)	8.12 × 10 ⁻⁷ (.388)	$5.62 \times 10^{-7} \text{ (.358)}$	$3.62 \times 10^{-7} \text{ (.321)}$	$3.70 \times 10^{-7} (.331)$	$1.23 \times 10^{-7} (,239)$	2.44 × 10 ⁻⁷ (.303)	2.71 × 10 ⁻⁸ (.133)		1.74 × 10 ⁻⁹ (.029)
Contribu- tion of e elements Li to Ni	11 from	1.82 × 10 ⁻⁶ (.871)	1.29 × 10 ⁻⁶ (.822)	8.93 × 10 ⁻⁷ (.790)	8.66 × 10 ⁻⁷ (.773)	3.47 × 10 ⁻⁷ (.672)	5.84 × 10 ⁻⁷ (.726)	9.77 > 10 ⁻⁸ (.479)		
Total dos equivalen rate (rem	e- t	2.09 × 10 ⁻⁶	1.57 × 10 ⁻⁶	1.13 × 10 ⁻⁶	1.12 × 10 ⁻⁶	5.16 × 10 ⁻⁷				
		2.09 × 10 ⁻⁶ re the relative dose-					8.04 × 10 ⁻⁷	2.04 × 10 ⁻⁷	5.41 × 10 ⁻⁷	5.92 × 10"

*The numbers in parentheses are the relative dose-equivalent rates and were obtained by dividing the dose-equivalent rate due to each incident ion species by the total dose-equivalent rate.

decrease of the absorbed-dose rates and dose-equivalent rates due to unattenuated primary particles as the shield thickness increases. Because of the higher energies considered here, additional shielding is not very effective in decreasing the dose rates due to unattenuated primary particles. When nuclear attenuation is included in the calculations, the dose rates decrease significantly with increasing shield thickness, but, in considering this, it must be remembered that nuclear attenuation implies the production of reaction products, and no estimate of the dose rates from these reaction products, except in the case of incident protons, is available. In Chapter 7 it was shown that in the case of incident galactic cosmic-ray protons an underestimate of the absorbed-dose rate and dose-equivalent rate was obtained by using the unattenuated primary-proton flux to obtain dose-rate estimates. The solid curves, labeled "TOTAL," at the top of each figure give perhaps the best estimates of the dose rates from galactic cosmic rays that can presently be obtained, but the values shown must be considered to be very approximate and may underestimate the actual dose rates by a considerable amount. It should be noted that the unattenuated primary-proton dose rates were used in obtaining the total dose rates shown in Figs. A4.1 to A4.4, and therefore, because of the data given in Chapter 7, these total dose rates are known to include an underestimate of the proton contribution. To obtain the doses that would be received on an extended mission outside of the earth's magnetosphere, the values given in the figures must be multiplied by the mission duration in seconds. It can readily be seen that a serious radiation hazard exists if very long missions are considered.

The relative contribution of each incident-particle species to the total absorbed-dose rate and dose-equivalent rate for several shield thicknesses

is also shown in Tables A4.1 to A4.4. With attenuation neglected, the relative contribution to the absorbed-dose rate from the sum of the heavy nuclei, i.e., nuclei with A > 4, is roughly comparable to the absorbed-dose rate from protons and alpha particles, and this relative contribution of the heavy nuclei changes only slowly with shield thickness. With attenuation included, the relative contribution to the absorbed-dose rate from the sum of the heavy nuclei is comparable to that from protons and alpha particles for thin shields, but the relative contributions from alpha particles and the heavier nuclei decrease significantly with increasing shield thickness. With attenuation neglected, the relative contribution of the sum of the heavy nuclei to the dose-equivalent rate is somewhat larger than the contribution of either the protons or the alpha particles, and the relative contribution of the sum of the heavy nuclei to the dose-equivalent rate changes only slowly with shield thickness. It should be noted that the nuclei in the Ti-Ni group contribute very appreciably to the dose-equivalent rate. With attenuation neglected, the relative contribution to the dose-equivalent rate from the sum of the heavy nuclei is important for thin shields, but the relative contribution of the alpha particles and heavier nuclei to the dose-equivalent rate decreases significantly as shield thickness increases.

The results presented in this appendix indicate that for extended space missions outside of the earth's magnetosphere the galactic cosmic rays present a significant radiation hazard, and an appreciable part of this hazard is due to the alpha particle and heavier nuclei components of galactic cosmic rays. Because of the very approximate nature of the calculations, the estimates of the dose rates from the alpha particles and heavier nuclei are not definitive, but until more reliable data become available, it seems clear

that the radiation hazard from these particles cannot be neglected if long missions outside of the earth's magnetosphere are considered.*

^{*}Some information on the dose rates to be expected from galactic cosmic rays on space missions within the earth's magnetosphere will be found in Ref. 119.

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